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DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

Report on Structural Materials along the St. Lawrence River, between Prescott, Ont., and Lachine, Que.

BY

Joseph Keele and L. Heber Cole

OTTAWA
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DIRECTOR'S PREFACE

In April, 1919, the Department of Mines received a request from the Dominion Power Board for a report on the structural materials in the superficial, unconsolidated and bed-rock deposits bordering the St. Lawrence river. The resolution asking for and defining the work required was as follows:—

It was resolved, that in addition to engineering data to be supplied the Dominion Power Board in reference to the St. Lawrence river navigation and power projects by the Public Works, Railways and Canals, and Marine and Fisheries Departments, and by the Ontario Hydro-Electric Power Commission, and any additional surveys undertaken by the Dominion Power Board, that it would be necessary for the Board to obtain information regarding the superficial deposits, of under surface rock structure of the river valley, as well as a critical survey of the building material of the vicinity for any possible future engineering structures, such as sand, gravel, stone, and materials for the making of cement.

That as this information can best be obtained by the engineers of the Department of Mines, the Chairman of the Board should be requested to present the matter to the Honourable the Minister of Mines with the request that the information already on the records of the Department of Mines be compiled, and that such information should be supplemented, where necessary, by field surveys during the coming season, and that such physical and chemical tests as will be required of the materials collected in connection with this investigation be made, as will further the objects of the examination.

As a result of this request, Messrs. J. Keele and L. H. Cole, of the Mines Branch, were assigned to the work. With a view to providing the desired information for the Dominion Power Board, relative to conditions in the region along the St. Lawrence river, in the provinces of Ontario and Quebec, it was found necessary—in order to supplement the data already in existence—to make detailed surveys of a strip extending from Prescott to Lachine, back from the river some six to twelve miles. The field work in connexion with this investigation was accomplished during the field seasons of 1919 and 1920; and the accompanying report was submitted by the Deputy Minister of Mines, on May 13, 1921, to the Dominion Power Board, which body made the following recommendations:—

OTTAWA, May 21, 1921.

Hon. Sir JAMES LOUGHEED, K.C.M.G.,
Chairman, Dominion Power Board,
Ottawa, Ont.

SIR,—

DEVELOPMENT OF ST. LAWRENCE RIVER, CONSTRUCTION MATERIALS

1. If and when it be decided to undertake the further navigational and power development of the St. Lawrence river one of the problems will be that of supplying the structural materials, such as sand, gravel, and rock, that will be necessary in tremendous quantities for the making of the huge concrete structures that will be required.

2. In view of the foregoing this Board suggested to the Mines Department, through the Chairman of the Board and the Minister of Mines, that such inspection and survey be made of the St. Lawrence district as would show what structural materials are found in the territory contiguous to the river, their qualities, and in what quantities they are available.

3. The Mines Department very kindly undertook this work and have now forwarded a report thereon, attached hereto for your information. It is obvi-

ously a very fine document, the result of much painstaking labour combined with complete technical knowledge of the subject, and one that will undoubtedly be of great use to all those concerned with the engineering side of the development of the river, besides being of much help to industries, present or prospective, that use such materials and are interested in the St. Lawrence territory.

4. In view of the completeness and great value of the report, we take pleasure on behalf of the Board in both acknowledging the great assistance which the Mines Department has given by making it, and in strongly recommending that it be published, with its accompanying maps, as soon as possible.

Respectfully submitted on behalf of the Board,

(Signed) **A. St. Laurent,**
Vice-Chairman.

(Signed) **J. B. Challies,**
Secretary.

Pursuant to the above recommendation, and in conformity with the publication policy of the Department of Mines, this report is now being made available for public distribution.

(Signed) **John McLeish,**
Acting Director Mines Branch.

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CHAPTER I

INTRODUCTORY

HISTORICAL OUTLINE

In the early part of 1919, instructions were received by the writers to make a survey of a portion of the valley of the St. Lawrence river, situated in Ontario and Quebec.

This work was undertaken at the request of the Power Board of Canada. The object of the survey was to examine and sample any deposits of material which could be used for structural purposes; also to ascertain the character of the bed-rock and overlying unconsolidated formations, in so far as they affected the storage of water or the deepening and deflection of the present canal system.

It was found, at the outset, that it would be necessary to make a complete geological map of the district, as no maps of the kind were in existence. A map, showing the supposed bed-rock formation underlying the area included between the Ottawa and St. Lawrence rivers, was published by the Geological Survey in 1906; but, inasmuch as this region is almost entirely covered by unconsolidated material, and outcrops of bed-rock are so small in extent, and scattered, the existing map was unsuitable for the present purpose.

The unconsolidated materials with which the surface of the region is strewn are due, entirely, either directly or indirectly, to glaciation. These materials are known as the drift sheet, because, in most instances, they have been shifted from their places of origin by ice action. The melting of large bodies of land ice, together with submergence and emergence of the land surface from under sea water, has, to some extent, washed and sorted the glacial drift, and furnished materials of construction, such as sand, gravel, and brick clay.

A survey of the available road materials along the north side of the St. Lawrence river between Prescott and Montreal was completed and the results published, before the general work outlined above was undertaken, otherwise that report would have been incorporated in the record of general results here given.

The testing of materials and the experimental work in connexion with this report were done by the writers and their assistants in the laboratories of the Mines Branch of the Department of Mines, Ottawa.

45 samples of brick clay; 24 samples of sand and gravel; 4 samples of bed-rock; and 3 samples of boulder clay, were collected and examined.

The entire investigation in the field and laboratory occupied about nine months during 1919 and 1920.

LOCATION AND AREA

The area included in the investigation along the St. Lawrence river reaches from Prescott to Lachine, a distance of 100 miles, and extends back from the

river from 6 to 12 miles. Within this area are the southern portions of Grenville, Dundas, Stormont, and Glengarry counties, in the province of Ontario. Investigation and mapping were done on both sides of the river in the province of Quebec, so that portions of Chateauguay, Huntingdon, and Beauharnois, on the south side, and Soulanges, Vaudreuil, and Jacques Cartier counties, on the north side, are shown on the map.

The entire area covered by maps and report is about 1,030 square miles.

MAPS

For convenience of handling and reference, the map is published in three parts, on a scale of one mile to the inch. The map sheets are named after the principal towns in the area. From east to west they are called, respectively: Morrisburg, Cornwall, and Valleyfield sheets.

The base used was the maps published by the Department of Militia and Defence, with the contours omitted.

The geology was done from the roads and from paced traverses across country between each road. If the area between roads was large, more than one traverse was made across it.

The different kinds of superficial materials are shown by various colours.

Although the classification of the superficial material as shown on the map is a sound one, based on the essential character of each distinct member of the drift series, yet these materials grade into one another or overlap in such a manner that the rigid boundaries shown between them, for mapping purposes, does not in many cases hold true in nature. For example, the stoneless marine clay overlaps and thins out on boulder clay, and cultivation on the marginal area between them brings to the surface some of the stones in the boulder clay, so that there is a mixture of marine and boulder clay over a certain strip.

The sand which overlies the marine stoneless clay varies in thickness from a few inches to ten feet. In this case, it is necessary to adopt some rule in mapping areas over which the sand covering is thin. We have, therefore, mapped as clay, those areas where the sand above the clay is less than a foot in thickness.

The boulder clay or till varies widely in character. In some localities it contains very little clay, being mostly composed of sand and stones. In other localities clay is the predominant constituent. We have mapped the clayey and sandy boulder clays under one colour because they are the general till sheet or ground moraine of the region.

An effort has been made to delineate sand deposits according to their origin and manner of deposition; consequently, we have used different colours for sands which very often have a similar texture and appearance; but the shape of the deposits and their place in the topography of the region are sufficient to differentiate them.

The size of the gravel deposits shown on the map is frequently exaggerated, in order to emphasize the occurrences. Sometimes, however, the gravels may exceed the limits outlined for them.

The areas mapped as swamps are nearly always covered with a more or less dense forest growth. Most of these areas are wet underfoot during a portion of the year, but in summers of light rainfall they may be dry, while in other

areas surface water is always visible, except in winter. High and dry areas of forest land have the surface formation shown in colour, as far as it could be determined.

The maps will be found useful as a basis for soil surveys and, in fact, can be used for that purpose as they are. It would be better for agricultural purposes, however, if the boulder clay areas were differentiated into the various soil types, depending on the clay content. There are rather extreme soil types in this formation.

As already stated, the work was undertaken with certain definite objects in view— mainly economic; and since the time devoted to it was short, many inaccuracies may be found, particularly in the question of boundaries between formations.

The following report differs from most of the reports hitherto published by the Department of Mines, inasmuch as it aims to give a complete account of the geology, topography, and economic materials of a region, as well as a complete technological report on the properties and uses of all the materials within its boundaries, in so far as they apply to the scope of the department.

The portion of the island of Montreal shown in the Valleyfield map was taken from the map which accompanies the report on the Pleistocene and Recent Deposits of the Island of Montreal, by J. Stansfield, Memoir 73, Geological Survey, Ottawa.

PREVIOUS WORK

Geological.—The geological work previously published on the area covered by the three map sheets is very meagre, and consists mostly of incidental references in the reports of the Geological Survey, or in papers published elsewhere by members of the Survey staff. Probably the most important work was carried on first by Sir Wm. Dawson, whose nomenclature for the various formations in the Pleistocene series forms the basis for the classification adopted in this report. His work was followed up by several men on the Survey staff, notably: Giroux, Ells, and Chalmers. Short reports by these writers are mentioned in the bibliography.

The bed-rock geology of the district has been shown on the Cornwall sheet (Geol. Survey, Map No. 120) and the S. W. sheet of the Eastern Townships map (Geol. Survey, Map No. 571, Montreal sheet), both by R. W. Ells.

Among the more recent reports on the area covered in this report is one by J. Stansfield on the Pleistocene and Recent Deposits of Montreal island. This work was carried on in sufficient detail to be used for the section of Montreal island which is included in the Vaudreuil sheet.

Economic.—Considerable data relating to the economic possibilities of the district have been published in numerous governmental and other reports; the principal ones being listed in the accompanying bibliography.

ACKNOWLEDGMENTS

The writers wish to extend their hearty thanks to a number of gentlemen for their kindly services in supplying information and data relative to the subject of this report: notably, Mr. M. C. Hendry, of the Ontario Hydro-Electric Commission, Morrisburg, for permission to examine the drill cores obtained

from the bed of the St. Lawrence river at Morrisburg; Mr. D. W. McLachlan, of the Department of Railways and Canals, for numerous sections and records of drill holes; Mr. George P. Howley, resident engineer, The Cedar Rapids Manufacturing and Power Co., Cedars, Que., for sections and numerous records of drill holes; Mr. W. A. Robert, Beauharnois, for maps and other kindly services; and many others.

The section on "Road Materials" incorporated in this report was prepared by Mr. Henri Gauthier, and the Appendix by Mr. E. J. Whittaker and Miss A. E. Wilson, of the Palæontological Division of the Geological Survey.

Mr. J. Ross Taylor acted as field assistant during the field season of 1919, and Mr. Massie Baker during 1920. Both gentlemen performed their work in a satisfactory manner.

Mr. J. A. Robert, of the Borings Division, Geological Survey, spent six weeks with the writers in the field during the season of 1920, procuring well records in Soulanges and Beauharnois counties, province of Quebec. His long experience in the Borings Division of the Department of Mines enabled him to render valuable service in interpreting the information gathered from well drillings, and in sifting the evidence regarding the topography of the bed-rock surface concealed beneath the drift cover; while his ability to talk French made greatly for progress in a rural district where the French language is almost exclusively spoken.

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CHAPTER II

GENERAL TOPOGRAPHY AND GEOLOGY

GENERAL TOPOGRAPHY

The St. Lawrence river flows over an undulating plain in which it has carved scarcely any valley. Furthermore, its banks are generally low compared with the size of the stream.

Between Prescott and Cornwall, the St. Lawrence river has an average width of about a mile. At two places on its course farther east, there are expanses four to six miles in width, namely, lake St. Francis, below Cornwall, and lake St. Louis, below the Cascades rapid. The mean level of lake Ontario and of the St. Lawrence through the Thousand islands is 246 feet above tide. At Prescott it is 244 feet; at lake St. Francis, 153 feet; and at lake St. Louis, 69 feet.

The highest land in the Morrisburg sheet is about four miles north of Prescott, where an elevation of 375 feet is reached; which means an extreme relief of only 131 feet. The highest land in the Cornwall sheet is at the village of Northfield, where the highest elevation in the region mapped (352 feet) is reached. This is 199 feet above mean water level below the Cornwall canal. The greatest relief is in the Valleyfield sheet, where the sand plateau of St. Lazare rises 231 feet above the mean level of lake St. Louis.

The area mapped, as a whole presents four fairly well distinguished topographical provinces; a morainal belt about 12 miles wide in the western part of the Morrisburg sheet; a wider morainal belt in the Cornwall sheet; between these a flat or gently rolling intermorainal area; and east of the Cornwall moraine, a region that is mostly a low flat plain, made up of marine sediments.

The whole area is so covered with glacial drift, and rock exposures are so infrequent, that the mapping of bed-rock formation boundaries is uncertain and unsatisfactory: therefore, no attempt has been made to show them, and only the actual outcrops, as far as they could be found, are shown on the maps.

Influence of Bed-rock

For the most part, the influence of the underlying bed-rock, which is, generally, almost flat lying, is reflected on the surface. The minor elevations in the morainal areas are mounds and ridges of heaped up drift materials.

Bed-rock outcrops, rising in successive, receding steps from the river at Prescott, to an elevation of 100 feet, present the appearance of the front of a cuesta. This is the only point at which the river can be said to have a valley. The land rises to a height of 30 to 40 feet above the river just north of Cardinal, 10 miles east of Prescott; but within four miles north of the river drops to a general elevation of about 10 feet above river level; and no bed-rock outcrops occur except at low elevations, close to the river banks. Evidently the cuesta whose escarpment occurs at Prescott only extends for a few miles along the river, as no evidence of it was found at any other part of the area.

It was observed that many of the stony ridges in various parts of the area were perched on bed-rock pedestals. The bed-rock, in most cases, is not visible

underneath the stony ridges, but well borings and the large amount of unworn slabs of rock in their vicinity indicate that the solid rock is not far below the surface.

The rapids on the St. Lawrence are all caused by the river flowing over bed-rock, and the six rapids that occur in the area are at these hard parts in the bed of the river. The bed of the river consists of unconsolidated drift material in the slack water portions, between the rapids.

Drainage

The overflow from the Great Lakes basins is carried by the St. Lawrence river. The influx of the Ottawa river adds a considerable amount to its volume, but it receives only an insignificant amount of water in its course between lake Ontario and the mouth of the Ottawa river. The interstream area between the Ottawa and St. Lawrence contributes very little water directly to it.

The land in the Morrisburg sheet rises gradually for a few miles from the bank of the St. Lawrence to the north, and then it slants northward toward the Ottawa valley. Consequently, all the water received by the St. Lawrence from the area is the run off from the narrow slopes adjoining the river, while the Nation river and its branches carry the principal part of the drainage to the Ottawa.

The watershed is only about one and one-half mile north of the river at Prescott. At Cardinal it is three miles to the north, and farther east gradually trends away from the St. Lawrence.

The drainage of the Cornwall area is nearly all carried by the Raisin river and its branches which discharge into the St. Lawrence at South Lancaster. These are small sluggish streams, meandering interminably among the ridges and knolls of the Cornwall moraine.

The Baudet and Delisle rivers farther east are of the same type, but while the upper portions of these streams drain the morainal areas their lower courses are over the flat marine plains east of the moraines.

Owing to the general flatness of one part of the region, and the maze of morainal ridges in another part, which prevent streams from taking the shortest and steepest route to the main river, a great part of the area is badly drained, and numerous patches of swamp lands exist. Furthermore, the slight fall of the streams renders the drainage of cultivated lands difficult, and constant dredging of existing streams and digging of ditches are necessary in order to dry the lands in the spring.

The drainage of Beauharnois county, which lies on the south side of the river between lake St. Francis and lake St. Louis, is carried by the St. Louis river, a small stream discharging at the village of Beauharnois. The headwaters of this stream are close to lake St. Francis, and the land surface there lies so low that during high water stages the lake overflowed considerable portions of it until restrained by a dyke built in recent years. The flow of the St. Louis river is augmented by a shallow ditch to lake St. Francis, which supplies a sufficient discharge for power purposes at Beauharnois during the summer.

The Chateauguay river entering the south side of lake St. Louis is the largest of the smaller streams within the area. Its head waters lie along the base of the highlands at the international boundary, and the drainage basin of its many branches covers the greater part of four counties.

Erosion

The form of the surface of the land is due to the various unconsolidated deposits left upon it during the different phases of glaciation, submergence under sea water, and subsequent uplift. Since its emergence, running water and wave action are the chief agencies that have altered or modified the appearance of the land surface. The alteration by water erosion, however, has been very slight.

The St. Lawrence river, evidently a new comer to its present position in the area, has not worn down a bed to any great depth in the glacial drift. Wherever bed-rock is encountered beneath the drift, so little work has been done on it that rapids with steep gradients occur. A great deal of the original drift on the course of the river still remains in the form of islands, some of which are built of stoneless marine clay, the most easily eroded member of the drift series.

The banks of the river show very little signs of wear, except at a few places where steep clay banks occur, which are liable to slump during seasons of excessive rainfall (Plate VI).

There are two reasons why the St. Lawrence does not do more work on its bed and banks, one being that extreme changes in the level of its waters do not occur owing to the natural reservoirs in the Great Lakes basin which control the discharge and confine the rise and fall of the river within narrow limits, and another being the absence of sediment. Materials like fine sand and silt which can be carried by rivers are the cutting tools with which it wears down its bed. The St. Lawrence is not provided with any of these, as they are dropped in the lake basins, from which it flows as clear water.

The small tributary streams of the area have not entrenched themselves on the land but practically flow on or near the surface (Plate III), except near the banks of the St. Lawrence, where they cut little valleys more or less steep sided according to the material in the banks (Plate I).

Many of the morainal ridges have beaches built along their southwest flanks, generally about the 300-foot level. The beach material has been derived by wave erosion of the ridges, but this action is somewhat compensatory, because, while there is reduction at one point along the ridge there is filling at another, the fine material only being carried away. The stones and boulders on the surfaces of many of the ridges (Plate XVI) are the residual materials which were too heavy to be removed by the waves. The annual rainfall removes a quantity of fine material every year from the upland, and the amount increases as deforestation and cultivation is extended.

Some of the sand ridges in the eastern part of the Morrisburg sheet have been denuded of their forest growth, and cultivated. The wind is beginning to drift the sand and reduce the height of the ridges (Plate XIII). This is the only example in the area of power of wind to reduce land forms.

SUPERFICIAL GEOLOGY

Glaciation

The presence of large blocks of granitic rocks utterly foreign to the area, and of ridges and mounds of fluviatile gravels placed without any reference to ordinary land drainage, and the general absence of deep weathering, are among the more obvious evidences of Pleistocene glaciation over the area.

The principal change that glaciation makes in a region is, by the removal of most of the old pre-glacial material such as decayed and loose rock and old soils, and substituting freshly scoured rock surfaces and new soils.

During the maximum stage of glaciation the region appears to have been occupied by an ice-cap several hundred feet in thickness; but it is in the following period, when the ice was melting and land surfaces began to appear again, that most of the materials used for structural purposes were accumulated. A mass of ice moving over land accumulates a considerable amount of loose debris which works up from the surface of the ground and becomes incorporated in the ice, so that the lower portion resembles a concrete in which the aggregates are bound together by ice. When the rock aggregates are released by the melting of the ice, they fall in heaps, or spread out in a layer of varying thickness, according to the amount of debris contained in the ice. The water released by melting ice is frequently retained in channels under the ice, or else flows along its margins, washing, transporting, and sorting the thawed debris of glaciation. Many of the deposits in the mounds and ridges which reach from Ottawa to Prescott were formed in this manner.

Where the ice melts without any concentrated water discharges, a layer of unsorted material is laid down, usually conforming with the bed-rock surface below it. The comparatively flat area in Dundas county, between the Ottawa-Prescott and Cornwall moraines, carries a fairly uniform cover of till or boulder clay over a nearly flat lying rock surface. The numerous ridges of the Cornwall moraine are usually heaps of unsorted drift, and contain only occasional deposits sorted and arranged by running waters. It is evident that this belt has received more than its share of glacial drift, owing, probably, to readvances of the ice sheet between periods of waning.

Deposits of sand and gravel of glacio-fluviatile origin are occasionally concealed by a layer of till or unsorted drift of a later advance, and their presence is only revealed by well borings or by stream erosion.

The scratches and grooving seen occasionally on the few patches of bed-rock exposed were made by ice moving in a southerly direction in this area. Beyond the limits of the moraines the markings point to a movement toward the west. These facts suggest that an ice lobe persisted in the area after the general ice sheet had disappeared.

Land Submergence and Sedimentation

Whether the sea rose on the land, following the return of large volumes of water released from the American and European ice-caps, or the land was slowly subsiding as the ice-caps melted, it is evident that submergence followed in the wake of the waning ice. The consequence of this was that the land became covered with gradually deepening water and the glacial deposits became sea bottoms and received the sediments thrown down in the water bodies. The greatest depth to which this area sank or the height to which sea water rose upon it is registered by the highest marine beaches, remnants of which have been found at various points in the province of Quebec. The two points nearest the area under consideration at which the highest raised marine beaches exist, are on Covey hill, 23 miles southeast of Valleyfield, and on Rigaud mountain, 15 miles northwest of Valleyfield, at heights of 625 and 670 feet, respectively. Sea water then must have stood at a depth of over 300 feet above the highest

point in the area along the St. Lawrence, so that the combined basins of the St. Lawrence and Ottawa rivers formed an estuary bounded on the north and south by highlands very like the present estuary on the lower part of the St. Lawrence river.

A great quantity of clay and silt was deposited on the floor of this estuary and gradually filled in all the low places in the floor of glacial drift. The areas on which this clay lies now constitute the most desirable farming lands in the region, and also furnish the raw material for the manufacture of brick and tile.

Instead of rising at a uniform rate to its present level the land seems to have halted for prolonged periods at certain intermediate levels. Only two of these levels are registered in the St. Lawrence area, one at 300 feet and the other at about 100 feet above the present sea level. The portion of the area visible when the water stood at the 300-foot level was confined to a multitude of small islands representing principally the upper part of the highest ridges of the Cornwall moraine. A great number of these ridges have beaches built along their southwest sides, which appear to have faced the prevailing winds of that time. These beaches are the sources of the local supplies of road material and will be referred to in detail later on. The lowest standing water record above the present one has no economic significance. It is indicated in the terraces at various levels along the Ottawa river and on the St. Lawrence (Plate IX), which stand at about one to two hundred feet above the present sea level.

BED-ROCK GEOLOGY

A heavy mantle of unconsolidated material, varying from a few feet to 150 feet in thickness, covers the bed-rock almost everywhere in the region.

The St. Lawrence river has not quite succeeded in cutting down through this cover, so that, with only one exception,[1] outcrops of rocks are not visible on its banks in Dundas, Stormont, or Glengarry counties. At the western and eastern ends of the area shown on the map sheets, however, rock exposures are more frequent, and at Prescott in the west, and Melocheville and Cascades point in the east, the rock is exposed right on the river banks. In a few places in the channel, an occasional patch which stands at a higher level than the rest of the bed-rock of the district, is being scoured by the water; but everywhere else the river flows over clay, sand, or gravel. As stated elsewhere in this report, these outcrops of rock in the bed of the river cause the series of rapids which occur on the St. Lawrence between Prescott and lake St. Louis.

The chief information regarding the character of the bed-rock was obtained from small scattered outcrops, in some of which quarries have been opened in past years, to supply building stone.

Information was obtained also from diamond drill cores taken from the bed of the St. Lawrence river between Morrisburg and the New York state shore by the Hydro-Electric Power Commission of Ontario, and from borings made by the engineers of the Department of Railways and Canals, and by private companies in other parts of the river channel.

Although the amount of bed-rock accessible for inspection is meagre, certain generalizations can be made regarding its character as a whole.

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[1] At the southeast corner of Sheek island, rocks of the Chazy formation are exposed at a couple of points in the banks, about one foot above the level of the water.

The rocks of this portion of the St. Lawrence valley are made up largely of nearly flat lying beds of more or less pure limestones, magnesian limestones, dolomites, and shaly limestones, with a minor amount of shale. In the eastern part of the area, sandstone outcrops are frequent and at one locality north of Prescott, in the western part of the district, a small outcrop of quartzite was noted. In age, they include four subdivisions of the Ordovician rocks, viz., Trenton, Black River, Chazy, and Beekmantown; the Potsdam of Cambrian age; and quartzite of the Grenville series of the Pre-Cambrian. The following table shows the relationship of the different formations found in the area, arranged in descending order:—

Table of Formations in District Adjacent to St. Lawrence Canal System as shown by Fossils (collected)

Period	Formation	Lithology	Characteristic Fossils
Ordovician.........	Trenton..........	Limestone..............	Calymene senaria Parastrophia hemiplicata.
	Black River......	Limestone..............	Pianodema subæquata Tetradium cellulosum.
	Chazy[1]...	Magnesian limestone and shales.	
	Beekmantown....	Dolomites, magnesian-limestones, calcareous sandstone and sandstone.	Hormotoma anna. Isoteloides whitfieldi, Raymond.
Cambrian.........	Potsdam..........	Sandstone..............	Lingulepis acuminata (rare).
Pre-Cambrian.....	Grenville series...	Quartzite................	

[1]No fossils collected from this horizon. Included on the evidence of Ells map.

Description of Formations

Trenton Group.—The Trenton formation can be seen in several outcrops in the area investigated, a good example being exposed at the Mille Roches quarries. The rock consists mostly of fine-grained limestone, dark in colour, with numerous small fossils scattered through it. Exposed to the weather it turns much lighter in colour, and gradually exhibits wavy disintegration along the planes of bedding. This characteristic can be plainly seen in the blocks which are lying around the abandoned quarries. On examination with the microscope, the limestone is seen to be composed of calcite grains cemented together with calcium carbonate, kaolin, and small quantities of iron oxide.

Black River Group.—The Black River formation lies above the Chazy and below the Trenton. A typical outcrop of this formation is to be found three-fourths of a mile east of Bouckhill, lot 21, concession V, township of Williamsburg, Dundas county, Ontario. These rocks consist of dark grey to grey, compact, fine-grained limestones, generally carrying numerous fossils. [1] The beds are usually of sufficient thickness to allow of large blocks being quarried for building purposes.

Chazy.—This formation was seen at only one locality, namely, on the road half way between Chateauguay and Caughnawaga, Quebec. (See section in quarry under heading, Building Stones.) According to Dr. Parks, the Chazy formation is exposed in a quarry on the north side of Sheek island opposite Mille Roches.[1] He states that the workings are situated at a low level, so that they are flooded at seasons of high water. Evidently, this quarry was covered by water when the writers visited the island, as we did not see it. The rocks of this formation are mostly magnesian limestones, in some cases highly fossiliferous, with some fairly thick beds suitable for building purposes. The upper beds in the first quarry mentioned are badly broken up by joint planes, which traverse them in all directions, and there are occasional thin bands of shale, sometimes badly weathered, which are interbedded with the heavier beds. The thick beds show a fine-grained compact stone, with small crystals scattered throughout the general mass.

Beekmantown.—Probably the formation which is exposed in most of the outcrops noted is the Beekmantown. Practically all the dolomitic or calcareous outcrops encountered in the eastern end of the district are of Beekmantown age. West of Iroquois the rock exposures are all of this formation. The formation is made up of beds of varying thickness composed of siliceous dolomites, dense, grey, magnesian limestones, and a few thin beds of black shale. In nearly all the rocks of the Beekmantown formation examined vugs or cavities containing calcite, and sometimes barite or celestite were a notable feature. Some of the beds exhibit saccharoidal texture, and may be mistaken for fine-grained sandstones.

Potsdam Sandstone.—The Potsdam sandstone, the basal member of the Palæozoic, is well developed in the district between Beauharnois and Melocheville, at Cascades point, and on Isle Perrot. There are no exposures of this formation on the western part of the district. The rock consists of sandstones of varying degrees of hardness and purity, with some of the beds badly stained by iron oxide. There are, however, a number of localities where beds of a fair degree of purity can be obtained, and these lend themselves to the manufacture of a high-grade silica sand. The beds on the average are under one foot in thickness; but in places, such as the outcrop in the bed of the St. Louis river at Beauharnois, beds up to four feet in thickness can be obtained. This formation has furnished considerable building material (Plate XVIII).

Grenville Series.—Only one outcrop was noted in which the rock was of an age older than the Ordovician or Cambrian, and that was a quartzite ridge to the northeast of Prescott on lots 34 and 35, concession IV, township of Edwardsburg, Grenville county, Ontario. The exposure of quartzite is about one-third of a mile long, and about 150 yards wide at its widest part. Dolomite is exposed on all sides of the quartzite, and at one place where the contact between the two is bare, fragments of the quartzite are included in the dolomite.

1 The Building and Ornamental Stones of Canada, Vol. I, by W. A. Parks, Mines Br., Dept. of Mines, Ottawa.

CHAPTER III

PLEISTOCENE AND RECENT DEPOSITS

General Account

The various unconsolidated materials which are distributed over so much of Canada and the neighbouring parts of the United States are often referred to as the "drift," that is, they are mostly the products of glaciation laid down during Pleistocene time and have been moved from their places of origin. The principal member of the glacial series is known as till, or boulder clay: and these names are used interchangeably throughout this report. Till is the ground moraine or material released by thawing ice. It is a mixture of materials of all sizes and properties, varying from the finest grained clay to large rocks and boulders. Streams, beneath, upon, and along the margins of the melting ice, wash out and transport the earthy and stony materials, and distribute them in a more or less sorted condition; but the great mass of till remained untouched except by sub-aerial weathering; so that sand, gravel, and clay deposits—the products of washing processes by streams—are of rare occurrence over large stretches of country, although abundant at certain points. A reference to the maps of the strip of country along the St. Lawrence which accompany this report, show that boulder clay occupies the greater part of the superficial area. Owing to unusual conditions already mentioned in connexion with submergence, stoneless clay and fine sand are widespread over a part of the area, while gravel and coarse sand deposits are comparatively rare.

The thickness of these unconsolidated deposits overlying bed-rock is variable. Well records show up to 100 feet and more, and sometimes bed-rock is found a couple of feet below the surface. The average thickness of the deposits over all the area is about 50 feet. When various deposits are superimposed upon one another, the lowest, overlying the bed-rock, is boulder clay, although there is frequently a layer of loose blocks and fragments of bed-rock between the solid beds below and the boulder clay above. The stoneless clays overlie the boulder clay, and a layer of fine sand of varying thickness may overlie the clay (see Fig. 1). As a general rule, the boulder clay in this area shows no parting of

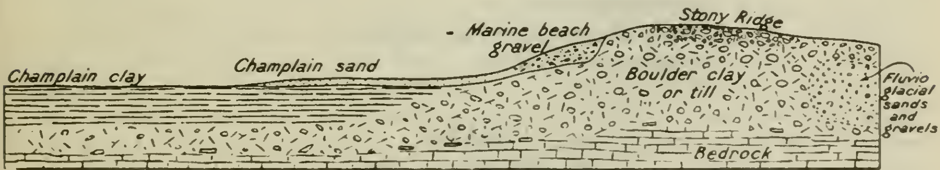

Fig. 1. Diagrammatic section showing arrangement of glacial and post glacial deposits overlying the bed-rock.

sand or gravel or other glacio-fluviatile material, as it does toward the western end of lake Ontario, although wells are frequently stated to have pierced stony clay and found water in gravel below it. None of the natural sections that we have examined show this sequence.

The marine or estuarine clay was deposited in the depressions of an uneven floor of glacial drift, and was the chief agent in producing the extensive plains in Soulanges, Vaudreuil, and Beauharnois counties shown on the Valleyfield sheet. It reduced the relief of the morainal ridges to some extent by filling in the hollows between them. The marked absence of lakes in these areas is probably due to this filling of depressions which would otherwise be lake basins. As the clay with its accompanying sand was the last formation laid down, it is quite probable that it covers and conceals many deposits of glacio-fluviatile gravels. It is difficult to detect the presence of these deposits from surface indications, but they have been found in digging wells.

The deposits classed as recent have been formed since the uplift, when what was formerly sea bottom became land surface, subject to the general conditions of stream erosion, sub-aerial weathering, and the support of a plant and forest growth.

The principal recent deposits within the area are those accumulated by the growth and decay of plants and trees in shallow, badly drained depressions. These depressions probably held open water at first; but they have since become filled with the products of decayed vegetable matter, and are now swampy areas, which support, for the most part, a thick forest growth. The material accumulated in these depressions in commonly termed muck when the decayed vegetable matter is mixed with mud, or peat, when it is free or nearly so from inorganic matter. The bottom of the depressions consist either of fine silty sand or clay. Lime carbonate or marl deposits—which frequently underlie swamps—have not been found, so far, in the area.

Rivers and streams often overflow their banks in the spring freshets, and spread over the adjoining land. A good deal of sediment is carried at these times, and is found in layers on the flooded land after the water falls back to the summer level. Such deposits as these are recent, and are still being laid down. There are very few areas of flood plain material large enough to be shown on a map within the area.

Fig. No. 1 is a diagram showing relations and sequence of the unconsolidated deposits in this region.

These materials were deposited in the following order:—

Recent.—Peat and swamp deposits, alluvial sands and silts.

Pleistocene.—Marine beach gravels.
Champlain sands.
Champlain clays.
Fluvio-glacial sands and gravels.
Boulder clay, or till.

CLAYS

Boulder Clay, or Till

The principal part of the unconsolidated material that covers the St. Lawrence area is boulder clay or till, an accumulation of stony and earthy substances of varying texture and character, which was gathered by the continental ice sheet from the surface over which it moved. As a rule the stones in the till are angular and not much worn, but there are many round or partly rounded

stones or pebbles included in it. Most of the angular stones are fragments from the underlying bed-rock of the district, which is limestone or magnesian limestone, and the well-worn pebbles are usually from crystalline rocks which occur in place in the region north of the Ottawa river. The boulder clay is unevenly distributed over the surface of the underlying bed-rock. In some places it is piled in irregular heaps, as in the morainal belts, but generally it presents an undulating surface with alternate swells and sags; and it is never quite flat like the marine or Champlain areas.

The large, scattered boulders or blocks of rock seen on parts of the area are not all confined to the surface, but are sometimes found imbedded at all depths in the boulder clay; but as a general rule the largest boulders occur in the upper part of the deposit.

Borings made for wells or other purposes frequently encounter these large blocks, and they may be mistaken for bed-rock if they are not pierced.

The boulder clay in this area appears to be all one mass and is not divided into an upper and lower part with layers of sand and silt between as it is in southwestern Ontario.

The composition of the boulder clay varies considerably throughout the region, the variation usually depending on the kind of fine material filling the spaces between the stones, usually called the matrix of the deposit. The boulder clay then may be classed in a bread way in three types, clayey, sandy, or gravelly, depending on the character of the matrix, and the soil survey man would probably subdivide these types. In another type of till large boulders or blocks of rocks form the larger part of the mass and the fine material the smaller. This type of deposit is treated separately under the heading "Boulder Deposits."

Good exposures of the till are found only on the banks of the St. Lawrence river, or on small streams at their point of entrance into the main river. Natural and artificial exposures are rarely seen inland, as the streams have not cut down very deeply, and the railways seldom had occasion to make any deep cuts. A good example of the compact, clayey type of till is seen on the banks of a small creek just below the highway bridge at the east end of Farran Point (Plate VII). This section is an example of the kind of till found widespread over a large part of the area. It is packed with angular stones and pebbles, but is not excessively bouldery. The stones are firmly held with plastic clay mixed with sand, and the bank forms a vertical face of this dense, compact material which is almost as resistant to weathering and erosion as some of the softer bed-rocks.

A steep bank about 50 feet high at the west end of Sheek island, just below the Long Sault rapid, is an example of an excessively bouldery till. A talus of heavy blocks of limestone and large crystalline boulders loosened from this deposit is accumulated along the bottom of the bank at the water's edge. The St. Lawrence river has cut through a ridge of similar composition just above the island, and the roughness of the rapid developed there is probably due to the presence of an interlocking mass of heavy blocks of rock which have been loosened from the ridge and accumulated on the bottom of the river. About five miles above Cornwall junction, on the Ottawa and New York railway, there is a cutting about 18 feet in depth through a ridge of till. This ridge consists mostly of sand with a little clay and a great quantity of angular limestone fragments 6 to 8 inches in diameter, and is a good example of the sandy type

of till. The part of the Ottawa-Prescott highway in Grenville county is mostly over sandy till. Other good sections of till are seen on the canal bank west of Morrisburg, and along the canal east of Dickinson Landing.

Clay and silt predominate generally in the composition of the boulder clays of Matilda and Williamsburg townships in Dundas county, and of Osnabruck township in Stormont county. The boulder clays of the township of Edwardsburg in Dundas county are of the sandy type, and those of Charlottenburg and Lancaster in Glengarry county are of the gravelly type. The most clayey type of till in the region is found in Chateauguay county, Quebec. The clay content of this till is so large and the stones so few and scattered in parts of the deposit that it is difficult to distinguish it from the sedimentary or Champlain clay.

The composition of the boulder clay and the variation of its ingredients are illustrated by the analyses of two samples taken from different points where pits were dug to a depth of three feet. The samples were dried and weighed, then washed in an excess of water, and the materials classified as follows: The particles which passed through a 200-mesh screen were called silt and clay; those which passed through the 100-mesh, but were too large to pass a 200-mesh screen, were classed as fine sand; material between 16 and 100-mesh was called sand, and between a 1-inch screen and a 16-mesh was classed as gravel; while larger than 1-inch was called stones.

	A	B
Stones	18%	22%
Gravel	34%	20%
Sand	5%	16%
Fine sand	10%	7%
Clay and silt	26%	35%

A. From trench beside Ottawa-Prescott highway, 2 miles south of Spencerville.
B. One mile north of Riverside P.O., Williamsburg township, Dundas county.

There is a greater quantity of coarse and less fine material in A, which gives it a more open and porous structure than B. The clay and silt content in B is more plastic than the same class of material in A. The effect of the larger quantity of plastic binder, and the finer texture of the coarser non-plastic ingredients is to make a more compact formation, almost, and in some cases absolutely, impervious to water.

The material in sample B was derived mostly from the limestone or dolomite bed-rock underlying the till. All the stones and over 95 per cent of the gravel were of this rock, and the sand was largely composed of limestone particles. The sand in sample A, on the other hand, was nearly all rounded quartz grains, which indicates that fluviatile material from a distance was mingled with the ground moraine.

The depth to which weathering has proceeded in the boulder clay of the St. Lawrence area is insignificant compared with the similar formation in southwestern Ontario, where weathering and oxidation reach as far down as 10 feet below the surface. In the St. Lawrence area weathering has not penetrated more than a foot or two into the glacial till. The coarse material washed from the sample in Williamsburg township was closely examined, but absolutely no indication of weathering was detected on the rock particles. The boulder clay thrown out from post holes and road trenches in the intermorainal area is always bluish-grey in colour, and no yellow coloration due to the oxidation of the iron content was observed. This shallow weathering may mean that a remnant of land ice persisted as a lobe over this area for a long period after the

ice had withdrawn from the land to the westward; furthermore, the long period during which this land was submerged below marine waters and protected from weathering while the land to the westward was probably dry, would help to account for the difference in oxidation.

The name hard pan is frequently applied to the boulder clay or glacial till. The lower part of it is often incredibly hard and difficult to excavate, and owing to its lack of cleavage or structural planes, it is not easily broken out by explosives. Contractors have repeatedly estimated for work on excavation in boulder clay on a clay classification, to find that the material is more expensive to remove than some classes of rock. The boulder clay makes the best foundation for buildings of any of the superficial deposits, and will support the heaviest kind of structures, if it is not deprived of lateral support, as may happen if much ground is taken out in the vicinity of the base of the foundations. In localities where there is an upper and lower boulder clay deposit, with stratified silt and sand beds between, the foundations of heavy structures are not so secure, as it is impossible to go down so deep in order to provide for a basement, that the footings of the structure are too near the silt beds, and consequently would not be secure.

A dam with its ends in the hard glacial till would be absolutely secure against leakage as far as that part of the structure is concerned; and the more clayey variety of till may be used for puddling. The soil types which result from the weathering and cultivation of the surface of the boulder clay naturally depend on the variations in its texture and composition. The glacial till soils in the vicinity of Ottawa are classified by Johnston as shale loam, stony loam, and sandy gravelly loam.[1]

There is no shale loam in the St. Lawrence area, but there are several other classes of glacial till soils there which are not found in the Ottawa area, such as fine sandy loam and silt loam.

Silt

The wet grinding of rocks in glacial processes gives a large output of fine-grained material called silt. All the boulder clays or tills contain more or less silt. Streams flowing over boulder clay areas carry clay, silt, and sand in suspension. Great alluvial deposits are often found on flood plains of rivers and in deltas or points of discharge of rivers into bodies of still water. Reduced velocity of water contributes to deposition of stream-borne sediments, so that sand and silt are deposited close to mouths of rivers, while clay particles remain longer in suspension and are carried farther before coming to rest.

Kemp defines silt[2] as a general name for the muddy deposit of fine sediment in bays and harbours, and one much employed in connexion with engineering enterprises.

Silt although fine-grained and composed of powdered rock, is only feebly plastic, and never as plastic and fine-grained as true clay. Silts are largely the result of mechanical action alone, while clays are the result of both chemical and mechanical processes applied to rocks. Silts are easily recognized by their flabby feel when moist. They have a tendency to adhere to the hand and to dry

[1] Memoir 101, Geological Survey, page 45.
[2] Kemp, J. F. A handbook of rocks, 1904.

quickly, while a true clay when moist feels like putty, does not adhere to the hand, and dries slowly.

Nearly all the surface clays throughout Canada are silty as a result of their glacial origin, while some of the deposits which look like clays are really entirely composed of silt or mud. A typical deposit is exposed between Woodlands and Dickinson Landing in Osnabruck township, Stormont county; the bank of the river is there made up of 12 feet of dark grey, stratified, slimy silt, overlain by 8 feet of sand. Water seepage occurs along the line of contact between the silt and sand, and waves from passing steamboats wash the silt at the base of the bank. The constant erosion by underground water and waves is slowly undermining the bank and endangering the highway built along it.

The surface material over a large part of the flat land in Beauharnois county, Quebec, near the east end of lake St. Francis, is more nearly a silt than a clay, although it is shown on the map as Champlain clay on account of the difficulty in determining the position of the boundary between silt and clay. The silt deposit in this locality may be due to periodical flooding of the land by the water of lake St. Francis, which deposited sediments of a silty character.

Silt makes a very unstable foundation, as it will flow under heavy loads and cause settlement. The lower beds of the Champlain clay are frequently composed of sticky silt which has a greasy feel. Many landslides have occurred on the banks of rivers, by the massive upper clay slipping on the greasy silts (Plate VI).

The silts are liable to cause trouble in borings or excavations on account of their tendency to slump like quicksands unless supported immediately, while the boulder clay or marine clay can be relied upon to hold a vertical face for a reasonable time.

The behaviour of silts and silty clays in working and burning in the manufacture of brick and tile is discussed in the chapter on Structural Materials.

In the table of tests of brick clays, Nos. 691, 696, and 710 are examples of silt.

Champlain Marine Clays

The deep-water sediments laid down during the submergence below sea level of the St. Lawrence and Ottawa valleys form a considerable portion of the actual land surface and subsoil of this region at the present day. These sediments were named the Champlain or Leda clays by Sir William Dawson.

Approximately three-fourths of the area included in the Valleyfield map sheet is covered by these clays. They form extensive plains on both sides of the St. Lawrence river, in Soulanges, Vaudreuil, and Beauharnois counties, at elevations of 140 to 180 feet above sea level (Plate V).

Sedimentation did not continue sufficiently long to form a deposit thick enough to cover the higher ridges in the morainal belts west of these plains; but the crests of some of the lower ones emerge or form swells or low humps in the plain, while many of the lower ridges are completely submerged under the cover of Champlain clay.

The greatest thickness and the largest continuous areas of clay in the region are represented on the Valleyfield sheet. The best sections where the structure of the clay can be observed are in the two terraces rising one above the other to a height of 100 feet above lake St. Louis on the south side of Isle Perrot. Sections up to 40 feet in height are exposed at many points in cut

banks on both sides of the St. Lawrence river, between Cedar and Cascade rapids, and on the north side, between Cedar and Coteau rapids.

The greatest thickness of marine clay is found in Vaudreuil county, south of Rigaud mountain, where several well borings pierced through 100 feet of clay, the deepest record being 130 feet.

The Soulanges plain extends into the Cornwall map area and occupies the greater part of the township of Lancaster in Glengarry county, but most of this plain is covered with a veneer of fine sand on top of Champlain clay. The Champlain clay, therefore, exposed at the surface, is confined to small detached patches lying in some of the depressions between the ridges and mounds of till, but the total extent of these patches forms a comparatively small portion of the surface material within the area.

The amount of Champlain clay exposed in the western portion of the Morrisburg map area is insignificant, being confined to a few narrow patches along the river front; but some of the large swamp areas in that district may be underlain by clay. There is a considerable expanse of plain east of the Ottawa-Prescott moraine which is underlain by clay, although it has a sand covering for the most part. The clay extends northward along the Nation river and its branches and appears to be continuous with the wide clay plains bordering the Ottawa river. The general altitude of this plain is about 250 feet in Edwardsburg township, or only 6 feet above the level of the river above Galop rapid.

The Champlain clay is of no great thickness in the Cornwall and Morrisburg areas. A large part of it is not more than a few feet thick, while a thickness of over 30 feet is rare, and good sections of the deposit are rarely exposed.

A considerable portion of the Champlain clay has been removed by river and stream erosion. Several of the islands in the St. Lawrence river are built of marine clay, and were evidently connected at one time with patches of similar clay on the banks. It is certain that the clay deposit extended right across the course of the river in an unbroken plain between the Coteau and the Cascade rapid before the river cut it away. The small streams have done only a minor amount of erosion in the clay, and in many cases have only removed the sand covering and laid the clay bare in the vicinity of their banks.

There is frequently a marked difference in the character of the upper and lower portions of the Champlain clay. The lower part is a sandy and silty clay, often well laminated, especially toward the base, but becomes more massive and less distinctly bedded in the upper part. The lowest part of the clay, however, just above its contact with the till, or whatever it may rest on, is seldom exposed in the region under discussion, and most of the sections available for examination are confined altogether to the upper clay; or the exposures may include several feet of a transition stage of silty clay which is not so stiff and plastic as the upper part nor so sandy as the lower part.

In general, the clay exhibits a marked similarity of appearance throughout the region as far as a casual inspection of the outcrops is concerned, and only by close scrutiny and testing of samples are differences in physical character determined. These general characteristics are the colour, which is uniformly lead grey, tending to brownish in the upper two feet, massive structure without partings or bedding, rather marked plasticity and smoothness when wet, and freedom from stones, pebbles, or coarse grit. The clay breaks down in irregular fragments, which frequently show a conchoidal fracture, and slakes readily on exposure to moisture (Plate VIII).

The base of the marine clay and the underlying till are seen along the banks of the small creek which enters the St. Lawrence at the village of Aultsville, 8 miles east of Morrisburg. A few layers of roughly stratified silt, sand or fine gravel generally occur between the massive stoneless clay and the till, but at one point the stoneless clay was found to rest on the till without any transition bed between them. The surface of the till rises irregularly going up stream, and the greatest accumulations of stratified material appear to be contained in hollows on the till surface; but along all the section the time during which stratified material was accumulated in shallow waters was very short before deep-water conditions of sedimentation abruptly commenced.

On the bank of the St. Lawrence, one mile west of Aultsville, stony boulder clay is exposed near the river level; overlying the boulder clay is about a foot of stratified silt carrying numerous pebbles and some large stones; above this there is a foot or two of irregularly stratified clay and silt without pebbles, grading upward into massive stoneless clay of the usual kind.

A small creek three miles west of Aultsville cuts through Champlain clay with a sand cover, at a point a few hundred yards north of the highway along the St. Lawrence. A section cut by the creek shows 4 feet of laminated grey silty clay at the bottom, with massive clay above, while farther up the creek and at a slightly higher elevation the bottom of the section shows stiff, massive, plastic clay, with a few scattered pebbles, for a thickness of 3 feet, and above this a similar but stoneless clay to the top of the bank.

The canal bank at the northwest end of Sheek island consists of 10 feet of sand underlain by 15 feet of dark grey, stratified silt, with some thin bands of fine sand. This section contains material similar to that in the bank of the St. Lawrence between Woodlands and Dickinson Landing, already mentioned under the description of silt, except that the fine, sandy layers are additional. The silt continues below low water level in both cases, so that neither the base of the section nor the underlying material is exposed. A layer of marine fossil shells occurs in a stratum near the water level in both localities. (See Appendix A).

The sections exposed in the cut banks lower down the river, in the province of Quebec, do not show a pronounced stratified, silty phase in this lower portion, like the two examples just quoted. In many cases, however, the lower parts of the Quebec sections are silty in character, but they are massive silty clays rarely showing partings or laminations, and differ from the upper clays only by being less plastic.

At various points along the small streams of the upland, sections of Champlain clays are exposed on the banks, but owing to the slight extent that the streams have cut downwards the sections are generally thin and only occasionally show the base of the clays. In some cases the massive upper clay is seen to rest directly on stony till, but at several points one or two feet of stratified layers of sand and silt are interposed between the clay and till. In some cases the clay rests directly on bed-rock or on fluvio-glacial gravels.

The evidence gathered in this region appears to indicate that as the ice melted shallow water bodies were ponded in depressions in the boulder clay surface vacated by the ice, and that coarse-grained stratified materials accumulated in these depressions. This stage was followed by gradually deepening marine waters in which the lower massive silts and, finally, the upper massive fine-grained clays were laid down.

A more detailed description of these deposits, together with their chemical and physical properties and uses, is given in the chapter on Structural Materials.

The Champlain clays have been examined for a distance of 300 miles along the Ottawa and St. Lawrence valleys, and the variations in the general character of these sediments are so slight that the observations and tests given in this report can be applied to their whole extent.

SANDS AND GRAVELS

Fluvio-Glacial Sands and Gravels

Stratified sands and gravels of fluvio-glacial origin are of local and irregular occurrence in the St. Lawrence area. These deposits are rarely exposed at the surface, being generally buried beneath a covering of marine deposits or till.

In general character the fluvio-glacial deposits are more sandy than gravelly, but in places they contain numerous large boulders and occasionally masses of till; they are generally markedly cross-bedded and show abundant evidence of minor folding and faulting due to the melting of included ice blocks and consequent settling, or to overriding by the ice sheet.

Sand and gravel deposits of this kind close enough to the surface to be worked appear to occur only in the morainal areas. Even there they are few in number, and there are none in the flat areas. There are doubtless many deposits of this kind unknown to us at present, buried deeply under other material. Occasionally in drilling wells, water-bearing gravels or sand are said to occur 20 to 50 feet below clay, and these may be buried fluvio-glacial deposits.

The form and composition of these deposits vary, and on account of the lack of surface indications it is impossible in most cases to trace out their form; and their composition is so variable that it is difficult to foretell whether sand or gravel is the more abundant, or whether or not they contain lenses of boulder clay. A deposit opened as a sand pit may eventually become a gravel pit, or vice versa.

The origin of the deposits is intimately connected with the melting and discharge of water from ice masses, which issued from tunnels beneath or flowed in open crevasses in the ice. In either case the debris from the ice was washed, sorted, and deposited in more or less confined channels which were of a temporary nature. The roof of the tunnel would fall in, or the walls of the crevasse collapse and cover or confuse the sands and gravels already accumulated. Sometimes the ice re-advanced over the fluvial material that it had laid down, or submergence of the land and deposition of sediments effectually concealed them.

In contrast to these buried or partially buried deposits there are several heaps and ridges of sand which often rise to 50 feet above the level of the surrounding country. These sand mounds are scattered irregularly through the southern part of the Ottawa-Prescott moraine. Certain features of these mounds, such as steep slopes toward the windward side, and long branching ridge forms, seem to point to a fluvio-glacial origin for these sands instead of accumulations by wind action.

The best examples of fluvio-glacial material are the Proctor gravel pit, one mile south of St. Raphael, and the Mitchell gravel pit, one mile southwest of Glen Gordon, both in Glengarry county, Ontario, the McIntosh gravel pit, one and one-half mile south of Spencerville, and the Spencer gravel pit, one mile

east of Ventnor, in Grenville county. An extensive deposit of this class also occurs in Soulanges county, Quebec, parallel to the lower part of the Baudet river.

All these deposits are freely drawn upon for sand and gravel for use in concrete construction. People often come to these pits for loads of gravel from distances of 10 to 15 miles, as the material is better for this purpose than the beach gravels.

Marine Beach Sands and Gravels

Certain ridges, particularly those throughout the Cornwall moraine, have thin gravel deposits built along their flanks, particularly on the westerly side. These gravels occur at the same general elevation, about 300 feet above sea level. They appear to mark a stage in the submergence or emergence of the land when the water stood at that level long enough for the waves to build beaches on what was then a large group of islands in a shallow sea. As the only source of material was on the islands, and as the islands were built of till or boulder clay, the action of the waves was to wash away the finer material and leave the pebbles, stones, and boulders more or less sorted.

Most of these deposits carry an abundance of marine fossil shells, mostly in fragments; but there are also numerous entire shells, and even shells still joined together. The shells are found among the gravels to a depth of 15 feet below the surface, which would make it appear as if the gravels were formed by a rising water body.

The beach gravels are generally of small extent, a thickness of more than 20 feet being unusual, and many of the deposits are not more than 6 feet in depth. Their superficial area is usually of limited extent, and a strip of beach gravel a hundred yards wide and half a mile long would be considered a large deposit of this class. The floor and back of the gravels is till or boulder clay. The materials of the beaches consist of coarse sand, fine and coarse gravel, cobblestones, and boulders. Some of the boulders appear to have been contributed by floating ice stranding and melting on the beaches.

The beaches are generally cleared and cultivated, and in many cases are used as sites for houses and farm buildings, on account of the good drainage and dry cellars that can be secured on such a foundation. Very good examples of beaches with well defined crest lines and finely modelled bars are to be seen in this region (Plates X–XIX), but in some cases the beaches are scarcely distinguishable as special forms on the ridges. The beach deposits contain more rounded pebbles, and less sand, and are more weathered than the fluvio-glacial gravels.

Many of the large beach gravel deposits are limited in their usefulness owing to the high percentage of cobblestones and boulders intermingled with the finer materials. These stones are too large to enter into a concrete mixture or to use for road materials, hence the local users, in the absence of a stone crusher, are forced to reject a considerable portion of most of these deposits (Plate XXIII). These beach deposits have hitherto formed almost the only source of road material in large sections of the area, and as there are several such deposits conveniently situated they are of considerable importance on that account. It is probable that under the new system of provincial road building which uses crushed field stone for road surfacing, the beach gravel deposits

will become only a secondary source of supply for this purpose. They will always be drawn upon, however, to furnish material for concrete construction on a small scale in the farming communities.

Champlain Sands

The Champlain marine sands or Saxicava sands, as they were named by J. W. Dawson, are spread over a considerable portion of the marine clay flats in the St. Lawrence areas. The sands belong to the same general period of deposition as the marine clays, but differ from them in origin, in that they were shallow water and near shore deposits, whereas the clay was deposited in somewhat deeper water. They were laid down chiefly at the time of emergence of the land and were deposited in the shallow waters near the shores as the sea gradually receded, being derived very largely by wave and current erosion on the shores and shallow bottom. These sands vary from a few inches thick on the flat lands to 12 feet near those places where hills and ridges of glacial drift supplied an abundance of material easily erodible by the waves and currents. The low-lying areas east of the Cornwall moraine are covered by sand, chiefly washed from the morainal ridges, and this sand is generally thicker near the margin of the moraine.

The great sheet of sand spread over the flat land in Grenville and Dundas counties is derived from material washed by waves from the sandy ridges of the Ottawa-Prescott moraine and carried by currents set up by the prevailing westerly winds. The sands are spread out over areas of both glacial drift and marine clay as far as 10 miles east of the moraines.

There is a marked absence of sand over the parts of Beauharnois and Chateauguay counties between lake St. Francis and lake St. Louis. It is possible that no Saxicava sand was ever laid down there on account of the absence of any elevated surface from which materials could be derived; or, the St. Lawrence river may have flowed for a time over this area and carried away the sands.

The marine sands vary in character from very fine sand to coarse sand and gravels and are usually somewhat oxidized and yellow in colour. They are finest in the nearly level areas where they overlie the marine clay. The near shore deposits are coarser grained and often diagonally bedded, or cross bedded.

The areas underlain by Champlain sands are for the most part under cultivation, but where the sand becomes too thick, or where a gravelly soil lies beneath it, cultivation becomes impossible from lack of moisture during dry periods in summer. Cultivation is maintained on the sand only by repeated applications of stable manure. This treatment produces in time a dark sandy loam to about the depth taken up with the plough. Farmers are careful not to plough too deeply in this ground, because they are liable to take up too much of the barren yellow underlying sand.

There are particularly barren areas in the townships of Edwardsburg, in Grenville county, and Matilda, in Dundas county, where the sands are thick and form an undulating surface, with occasional low dunes or ridges. Cultivation after clearing appears to have been general over this area, but much of it is now abandoned for this purpose and is covered with patches of small poplar.

The best farming lands in the region are those overlain by a thin veneer of Champlain sands, such as the flat lands in Lancaster township, in Glengarry

county, Ont., and in portions of Soulanges county, Que. In these areas the underlying clay is close enough to the surface to retain the moisture, while the sand cover ameliorates the stiffness of the clay and renders it more easily worked.

The Champlain sands are mostly very fine-grained and silty, so that they are not of much use as structural material.

Alluvial and Dune Sands

These sands occur adjacent to the St. Lawrence river along parts of the terraces which mark a former level of the river, before it had cut down to its present bed. The terraces are not continuous, as they have been to a large extent cut away by the present river; furthermore, they do not carry sand except at some localities, therefore these deposits are not very extensive, and are seldom more than a mile wide and a few miles long.

The best example of these alluvial, sand-covered terraces occurs above the immediate bank of the river between Farran Point and Dickinson Landing, in Osnabruck township, Stormont county. The terrace there is 29 feet above low-water level; it is from an eighth to a quarter of a mile wide and is overlain by yellow sand which is 12 feet thick in some places. Just east of Dickinson Landing and south of the village of Wales, a depression two miles long, which appears to be an abandoned channel of a part of the St. Lawrence river, is bordered on both sides by sand terraces which stand at the same elevation as the terrace which faces the main river. Sand-covered terraces that correspond to these and seem to have formerly been continuous with them are found along the north shore of Sheek island. There is a wide terrace partly covered with sand and silt between Morrisburg and Aultsville, the sands there being partly blown into low dunes. Occasional fragments of alluvial sand-covered terraces remain in the vicinity of Cornwall, Ont.; but east of Lancaster the terraces are absent and the sand of the marine plain covers most of the area adjacent to the river. Most of the terraces in the province of Quebec are entirely of clay, and rarely have a sand cover; but a small patch of sand occurs on the clay terrace on the south side of Isle Perrot.

The terrace sands are old river material and have been deposited by small tributary streams discharging sand into the main river, the source of the material being the Champlain sand deposits, and to a less extent sand washed from boulder clay. Being twice worked over by water these sands are more oxidized, more mixed with silt and probably finer grained than the Champlain sands. It is in deposits of this kind that iron moulding sands for foundry use are likely to occur.

BOULDER DEPOSITS

Most of the boulders found on the surface of the ground in the St. Lawrence area occur in isolated patches of small area which stand at slightly higher elevations than the general level of the country adjacent to them. They are generally in the shape of a low narrow ridge or a small mound, and only rarely are there patches of boulders on a flat surface.

Boulder deposits are particularly abundant on the ridges of the Cornwall moraine in the counties of Stormont and Glengarry, Ont. The greatest accumulations of boulders in Quebec are found in the low ridges of Beauharnois

county southeast of Valleyfield and in Jacques Cartier county. Most of the surface of the flat areas underlain by Champlain clays and sands is entirely free from boulder accumulations, and they are only sparingly scattered over the nearly level area between the Cornwall and the Ottawa-Prescott moraines.

Some of the boulder-strewn ridges can be traced for a mile or more. They do not seem to have any definite arrangement; many of them run in a north-south direction, but others trend east and west, and most of them are curved, like morainal deposits generally.

It has not been definitely ascertained if the boulders on the surface of the ridges extend downward, but some of the ridges in which excavations have been made show heavy boulders for at least six feet below the surface. A section of a narrow boulder ridge, exposed on the bank of the St. Lawrence river at the village of Cedars, shows heavy boulders and large angular blocks of rock to a depth of 18 feet below the surface. The boulder ridge cut by the Long Sault rapid shows heavy boulders scattered throughout its mass. On the other hand, a railway cutting on the Ottawa and New York railway shows few large boulders at depth, although there are several on the surface of the ridge.

It appears that the surface character of most of these boulder ridges is a true index to the composition of their cores, and that they are boulder accumulations with a filling of sand and gravel in the spaces. The fine material has been carried away by wave action and later sub-aerial erosion, leaving the heavy stones projecting above the surface of the ridges.

The ordinary till sheet of the region carries scattered boulders, generally in the upper part of the deposit, which also become laid bare by erosion; but they are isolated and seldom form accumulations large enough to be classed as boulder deposits. The largest boulder seen in the area was an isolated granite erratic standing in a depression in Cornwall township, Stormont county, about 2 miles north of the village of Mille Roches. It is 17 feet 6 inches long, 9 feet wide, and 8 feet thick, and weighs approximately 135 tons. It had been transported at least 50 miles before coming to rest in its present position (Plate XVII).

The ground in some places on the stony ridges is studded so thickly with boulders as to defy cultivation (Plate XIV). Nevertheless, attempts have been made to bring a portion of them under cultivation, but usually the results have not justified the labour expended, as only a small amount of scanty pasturage was substituted for the more profitable hardwood forest (Plate XV).

Occasionally some land capable of cultivation is gained by the labour of piling the boulders and blocks in heaps and along the fence lines, but as a rule the stony ridges should be regarded as absolute forest lands.

Granitic rock, such as granite gneisses, syenites, and diorites, quartzite, and occasionally crystalline limestone are represented most frequently in the boulders of the region; and Ordovician limestone and dolomites are plentiful. There is less sandstone than any other kind of rock. Most of the boulders are hard and do not show much indication of weathering, but loose blocks of limestone from certain beds are undergoing rapid disintegration, owing to their shaly structure (Plate XVI).

The different kinds of stones are usually mixed in varying proportions but sometimes one kind of rock type dominates. Blocks and fragments from the underlying bed-rock formations often prevail in some of the stony patches, especially where the bed-rock comes close to the surface or in the vicinity of

outcrops. A stony patch one mile north of Moulinette contains almost exclusively limestone blocks derived from beds which outcrop a short distance to the east.

The early settlers used the boulders for fences, as that was the most convenient way of disposing of them, also as foundations for houses and barns, and even for building churches. In the province of Quebec the field stones were used extensively for building dwellings. Many of these houses, formerly built throughout the counties of Beauharnois and Chateauguay, are by far the best examples of domestic architecture found in the country to-day. The remains of old lime-burning kilns are widespread throughout the region, the chief raw material for lime being the limestone or dolomite boulders.

The boulder accumulations are beginning to be drawn upon as a source of road material, and their use is increasing under the new system of organized road construction throughout the two provinces. It is possible to assemble quantities of field stone at convenient intervals along almost any proposed highway, but certain districts are better provided in this respect than others, as may be seen by a reference to the maps which accompany this report.

The different kinds of field stone and their durability when crushed for road-making purposes are very fully described in a separate report.[1]

SWAMP AND PEAT DEPOSITS

The areas mapped as swamps are of three general types: swamps, bogs, and marshes.

Swamps

The formation of swamps in any district depends upon certain conditions, such as the retention upon the land surface of a sufficient quantity of water to prevent the complete decay of the vegetation thereon. In an ordinary forest, the rate of decomposition of vegetable matter is generally greater than in a moist area; but owing to oxidation on the floor of the forest there is no progressive accumulation of vegetable matter. If the forest floor becomes more wet than usual the process of decay is partly arrested, the accumulation of peaty matter begins; and if this process continues, it leads to the destruction of the trees which occupy the area. In most of the lands along the St. Lawrence, occupied by hardwoods, the natural gradients are sufficient to keep the land dry enough to prevent the formation of swamps. The permanent swamp areas support little or no hardwood growth, the indigenous trees being tamarack, cedar, and black spruce.

The chief distinction between swamps and bogs lies in the greater abundance of trees and shrubs in the former, and to the fact that in swamps the soil, or peat, is firmer. The soils of the swamps are, generally, a mixture of partly decomposed vegetable matter and mud of a dark colour, termed muck.

Bogs

A bog is an almost flat, fairly open area, relatively free from trees, except small scattered tamarack or black spruce, and covered with moss (usually sphagnum) and heath shrubs. The muskegs of northern Ontario and the western provinces belong to this class. The soil of the bogs, and of most of the muskegs, consists of peat—decayed mosses.

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[1] Bulletin No. 32, by R. H. Picher, Mines Branch, Ottawa.

Marshes

Marshes are open, flat, wet areas, usually covered by a thick growth of sedges and grasses; often with cat-tails, bulrushes, and reed grass, together with some small mosses and ferns. They seldom contain sphagnum moss, or heath shrubs, and are treeless. Such marshes are usually found adjoining lakes, or rivers, and are typically developed at various points along the St. Lawrence river, the chief marshes within the area mapped, being those on the north and south side of lake St. Francis. The soil of the marshes is always saturated with water, and is frequently flooded.

EXTENT OF SWAMP LANDS

The total area mapped along the St. Lawrence was 1,030 square miles; and in about 106 square miles of this area there are swamp conditions all the year round. These areas are distributed as follows:—

Swamp and Marsh Areas

Morrisburg sheet	53	square miles
Cornwall sheet	38	"
Valleyfield sheet	5	"
Total	96	"

Peat Bog Areas

Morrisburg sheet	0·5	square miles
Cornwall sheet	0·25	"
Valleyfield sheet	10·00	"
Total	10·75	"

The largest continuous swamp in the area is that north of Morrisburg, with a total area of 21 square miles.

RECLAMATION OF SWAMP LANDS

The need for the wholesale reclamation of the swamp lands on the St. Lawrence area has not been urgent, because there is so much farming land available; but if, in the near future, this district is called upon by reason of industrial development to support a much larger population than at present, some comprehensive scheme to drain and cultivate these lands should be adopted.

Present attempts at drainage consist merely of keeping the existing streams open so that the natural flow of water is not impeded. This system ensures that flood water does not remain too long on the low-lying portions of the farm lands; but it does not bring new areas of swamp land into use. Individual farmers occasionally dig drains deep enough to reclaim portions of the swamp lands on their properties, but success in keeping the reclaimed lands dry depends on the efficiency of the main drain, which is one of the numerous small creeks of the region.

The circuitous routes pursued by the small streams of the region from their source to the point of discharge into the St. Lawrence, the slight differ-

ence in level between these points, and the consequent low gradients of the streams make it difficult to utilize the natural drainage for reclaiming any large areas of land. The most effective method is the digging of a ditch over the shortest route from the undrained area to the St. Lawrence; but it is doubtful if any of the areas which could be unwatered by a single main ditch are large enough to warrant the necessarily large expense which the project would involve.

The largest swamp area in the region examined is situated in Dundas county, Ontario. A considerable portion of this area could probably be drained by deepening and improving the flow of Hoasic creek.

A systematic scheme for the drainage of this area was prepared by Mr. G. Brown, C.E., of Morrisburg, some years ago, but up to the present time his plans have not been adopted.

ECONOMIC VALUE OF SWAMP LANDS

Timber.—Some of the swamp lands which support a forest growth of tamarack, spruce, and cedar, supply timber for use as fence posts, railway ties, telephone poles, etc., but the best timber in most of the swamps has been exhausted.

Cultivation.—Some local attempts to drain and cultivate swamp lands were failures because the swamp was underlain by soils inadequate to the growth of crops. The principal failure was due to the wet land being underlain by sand, with only a thin layer of peat, or muck, on top. The peaty layer oxidized and disappeared when the land was dried, and the underlying sand was practically barren. In other cases the swamps are underlaid by hardpan or till, strewn with boulders, so that it would be futile to drain and clear them for the purpose of cultivation.

Large areas of swamp lands are underlain by muck, a mixture of carbonaceous matter and mud, and others by marine, stoneless clay. These are the kind of lands it would pay to reclaim.

It is, therefore, advisable to ascertain the character of the bottom of a swamp by boring and sampling before undertaking drainage operations. The lands underlain by peat in Huntingdon county, Que., are extensively cultivated. The upper layer of peat is first burned off and the remainder worked into the underlying clay.

Peat

There are few areas in the region examined large enough, or sufficiently deep, to be considered as a source of supply for peat fuel.

The nearest approach to a workable deposit of peat within the boundaries of the map sheets is situated in Huntingdon county, Que.

This bog was surveyed and sounded by Mr. A. Anrep during his investigation of the peat bogs of Canada, and a detailed description of it is given in his report.[1]

[1] Mines Branch. 1914. Bulletin No. 9, p. 5.

CHAPTER IV

STRUCTURAL MATERIALS OF THE REGION

BRICK AND TILE CLAYS

General Account

The stoneless clays, described under the name of Champlain or marine clays, are used for making brick and tile. Any clay in the region investigated that has stones or pebbles scattered through it is absolutely useless for brick or tile making, since most of the pebbles consist of limestone, and the presence of these is fatal to the durability of burned clay products.

The maps that accompany this report show the areas in which the stoneless or Champlain clays occur and their approximate superficial extent.

Samples were taken from some of these deposits by making borings or by taking advantage of natural sections exposed on river and stream banks. An average sample representing the clay deposit to a workable depth was in most cases obtained.

A detailed account is given in the following pages of the behaviour of these clays in the laboratory experiments, as regards their properties in the raw and burned states, and of their chemical composition. A description of the deposits which were sampled, and the uses of the clays, are also given, as well as a brief statement of the possible clay working industry based on these materials.

Composition of the Champlain Clays

The chemical composition of the common clays is not of much importance in determining their value for the manufacture of burned clay products, as it gives no indication of how the various clays will behave during the different stages of preparation and burning, and this is the kind of information the clay worker requires. The only way to find out the properties of clays of this kind is to submit them to the tests for working, drying, and burning, as was done in the preparation of the data for this report.

It is necessary, however, to know the composition of a clay if it is to be used as an ingredient in the manufacture of portland cement along with a suitable limestone or marl, or for certain other purposes; therefore, a number of the samples collected were chemically analysed, with the following results:—

Chemical Analysis of Champlain Clays

No. of Sample	692	692A	716	716A	720
Silica (SiO_2)	54·90	53·48	54·42	52·54	53·49
Alumina (Al_2O_3)	18·20	18·06	18·01	17·57	16·92
Iron (Fe_2O_3)	6·64	7·36	7·23	7·23	6·99
Titanium (TiO_2)	0·83	0·84	....	....	....
Lime (CaO)	4·68	4·62	3·70	5·03	4·59
Magnesia (MgO)	3·62	4·62	4·48	5·12	2·27
Potash (K_2O)	3·78	3·33	3·15	3·03	3·08
Soda (Na_2O)	1·36	1·75	2·52	2·78	2·14
Water (H_2O)	3·22	2·76	2·44	2·87	2·35

No. 692—East end of Sheek island, Ont. Average of upper 8 feet of bank.
No. 692A—East end of Sheek island, Ont. Average of lower 12 feet of bank.
No. 716—One mile west of Vaudreuil, Que. Average of upper 15 feet of bank.
No. 716A—One mile west of Vaudreuil, Que. Average of lower 10 feet of bank.
No. 720—One mile west of Beauharnois, Que. Average of 8 feet thick.

Analyst: Mr. A. Sadler, Mines Branch, Ottawa.

These clays contain a large percentage of fluxing impurities, the amount indicated by the analyses being 17 to 19 per cent, so that they are easily fusible, hence their use is restricted to the common grades of coarse clay products. The fluxing impurities in clays are iron, lime, magnesia, and the alkalies, potash and soda. When the sum of these in a clay exceeds 7 per cent, it is, generally, not refractory. Real fireclays usually contain much less than this. As far as we know there are no fireclays, or even semi-refractory clays in this region.

TABLE I

SUMMARY TABLE OF PHYSICAL TESTS ON SURFACE CLAYS IN EASTERN ONTARIO AND WESTERN QUEBEC

Locality	Lab. No.	Per cent water required	Per cent of drying shrinkage	Cone 010		Cone 06		Burned colour	Remarks
				Per cent fire shrinkage	Per cent absorption	Per cent fire shrinkage	Per cent absorption		
Edwardsburg tp., Grenville co., lot 33, con. VII, 2 miles W. of Spencerville village	721	30	11	2	9	2	10	Red	Fire checked.
Grenville co. about 2 miles E. of Prescott, bank facing St. Lawrence river.	703	30	9	1	15	1	14	"	Av. of 16′ section. Good for tile.
Edwardsburg tp., Grenville co., on Drummond island.	704	31	11	5	18	5	6	"	Fire checked, excessive shrinkage.
Edwardsburg tp., Grenville co., lot 11, con. I, just W. of canal entrance at village of Cardinal.	706	30	8	1	......	1	17	"	Av. of 20′ section on river bank. Good for tile.
Matilda tp., Dundas co., lot 24, con. IV, 1½ mile E. of Hainsville.	705	29	10	1	15	1	15	"	Av. of 8½′ auger hole. Good for tile.
Williamsburg tp., Dundas co., lot 32, con. VI	707	31	12	2	11	2	10	"	Av. of 4′ section, bank of creek. Fire checked.
1 mile E. of Weaver point, Dundas co	687	26	6	0	14	1	14	"	Average of bank.
1 mile E. of Weaver point, Dundas co	687a	22	6	0	14	1	13	"	Upper portion of bank.
1 mile E. of Weaver point, Dundas co	687b	30	8	0	15	1	15	"	Lower portion of bank.
From stream bank 1 mile N.W. of Aultsville	689	32	9	0	16	1	14	"	Good for drain tile.
Bank of creek at Farran Point, Stormont co	690	25	7	0	16	0	16	"	Av. of bank.
Bank of St. Lawrence river, 1½ mile W. of Dickinson Landing	691	22	5	0	17	0	17	Buff	Silt underneath sand
Osnabruck tp., Stormont co., lot 3, con. IV.	695	27	8	0	15	1	14	..	Upper clay, good for drain tile.
Osnabruck tp., Stormont co., lot 3, con. IV.	696	20	5	0	14	0	14	Buff	Lower clay
Cornwall tp., Stormont co., lot 25, con. VI	694	32	9	0	16	1	14	.	Good for drain tile.
E. end of Sheek isl., St. Lawrence river	692	37	10	1	15	......	14	...	Upper 8′ of bank.
E. end of Sheek isl., St. Lawrence river	692a	38	10	1	18	...	14	....	Lower 12′ of bank.
Near quarries 1 mile N. of Moulinette	693	37	10	1	14	3	2	......	Upper 6′ of borehole.
Near quarries 1 mile N. of Moulinette	693a	40	10	1	17	5	7		Lower 8′ of borehole.
Cornwall tp., Stormont co., lot 2, con. V	699	37	11	0	12	5	1	...	
Bank of Crays creek, Charlottenburg tp., con. I	697	38	13	1	13	6	1	.	Bloats on fast firing.
Bank of Crays creek, Charlottenburg tp., con. I	697	....	8	1	15	1	14	..	1 part sand to 2 parts clay.
Charlotteaburg tp., Glengarry co., lot 22, con. VI, 1 mile N. of Macgillivray's bridge	708	30	11	1	11	1	10	Red	Fire checked.
Charlottenburg tp., Glengarry co., lot 3, con. IV	700	37	10	0	18	3	14	"	Good for drain tile.
Lancaster tp., Glengarry co., lot 30, con. V.	698	27	8	1	12	1	13	"	Good for drain tile.
Lancaster tp., Glengarry co., lot 25, con. IV, 3/10 mile N. of N. Lancaster sta., C.P.R.	709	25	8·5	......	15	0	13	"	Av. sample of marine clay from well.
Lancaster tp., Glengarry co., lot 10, con. VI, ¾ mile S. of Dalhousie sta., G.T.R.	713	23	9	0	11	1	10	"	Good for tile.
Lancaster tp., Glengarry co., lot 9, con. V, ½ mile E. of Bridge End sta., C.P.R.	714	27	9	1	18	1	12	"	Av. of 6′ section.
Vaudreuil co., just S. of village of St. Lazare	715	31	10	2	14	2	13	"	Av. of 8′ of bank.
Vaudreuil co., just S. of village of St. Lazare	715a	19	5	0	15	0	1	"	Sandy loam overlying clay.

TABLE I—*Concluded*

SUMMARY TABLE OF PHYSICAL TESTS ON SURFACE CLAYS IN EASTERN ONTARIO AND WESTERN QUEBEC

Locality	Lab. No.	Per cent water required	Per cent of drying shrinkage	Cone 010		Cone 06		Burned colour	Remarks
				Per cent fire shrinkage	Per cent absorption	Per cent fire shrinkage	Per cent absorption		
Vaudreuil co., just S. of village of St. Lazare	715b	26	8	0	13	1	13	Red	2 parts 715, to 1 part 715a. Good for tile.
Vaudreuil co., 2½ miles W. of Vaudreuil village on C.P.R. (Toronto line).	716	36	10	0	15	2	15	"	Upper 15′ of terrace, brown clay.
Vaudreuil co., 2½ miles W. of Vaudreuil village, on. C.P.R. (Toronto line).	716a	37	8	0	20	1	19	"	Lower part of terrace, grey clay.
Vaudreuil co., 2½ miles W. of Vaudreuil village, on C.P.R. (Toronto line).	716b	19	6	0	11	0	11	"	Av. of 6′ from bank of stream.
Beauharnois co., about 4 miles NE. of St. Barbe	710	21	5	0	13	0	13	"	Sample of silty clay from drainage ditch.
Beauharnois co., ½ mile W. of St. Stanislas-de-Kosta, in ditch on road side	712a	40	11	1	11	5	6	"	Shows excessive shrinkage.
Beauharnois co., near road on N. side of St. Louis river, about 2 miles NW. of St. Louis de Gonzague	711	32	9	0	20	0	18	"	Av. 15′ auger hole. Scummed
Beauharnois co., near road on N. side of St. Louis river, about 2 miles NW. of St. Louis de Gonzague	711a	21	6	0	13	0	13	"	Upper 5′ silt.
Beauharnois co., 1 mile N. of St. Louis de Gonzague	712	30	10	1	18	1	16	"	Good for tile.
Beauharnois co., S. channel of St. Lawrence river, near E. end of de Salaberry island	717	30	11	3	11	4	9	"	Shows excessive shrinkage.
Beauharnois co., on river road, midway between Melocheville and St. Timothee.	718	32	11	0	17	1	16	"	Av. of 15′ section on river bank.
Beauharnois co., 1 mile W. of Beauharnois village	720	33	10	1	17	1	15	"	Av. of 7′ section in terrace.
Beauharnois co., at Maple Grove station, N.Y. Central	719	31	11	0	16	1	16	"	Av. of 8′ section in terrace.

There does not seem to be much difference between the top and bottom portion of the Champlain clay as far as the chemical composition is concerned, and in the case of the clay at Sheek island there is not much difference in the physical properties. The difference between the upper and lower part of the clay near Vaudreuil is quite noticeable from a working standpoint, as the lower clay is very silty, while the upper part is very stiff and plastic. The chemical analysis gives no clue to this difference; in fact, the lower silica and the higher water content of the lower clay would indicate that it was more plastic than the upper.

The amount of lime and magnesia present is quite large, but not large enough to interfere with the development of a good red colour in the burned product. When the amount of lime and magnesia, together, is equal to or greater than three times the iron, then the clay will burn to a buff colour. All the upper clays and most of the underclays in the region burn to red colours. The two samples of silty clays, 691 and 696, are both underclays, with a sufficiently high lime content to cause them to burn to buff colours.

Explanation of Physical Tests

The clays were made up for testing by grinding, wetting, and working them until the best working consistency for each sample was arrived at, and then moulding them into test pieces, 4 inches by 1½ inches by 1 inch in size. The clay requires different quantities of water for mixing, the amount varying according to the texture. The pasty, highly plastic clays require more than the silty, open working clays. Lab. No. 691 is an example of the latter type, and No. 692 of the former. The clays that require a large quantity of water in mixing are generally hard to dry, and any of the clays taking 30 per cent or

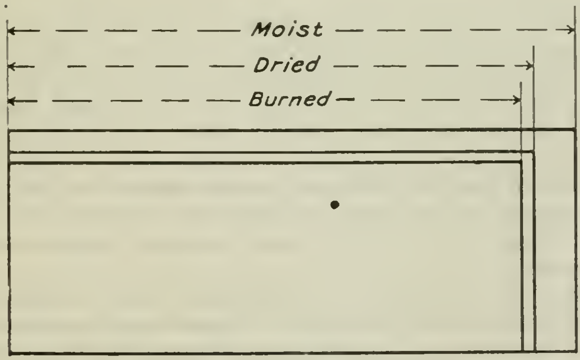

Fig. 2. Diagram showing successive stages of shrinkage of Champlain clay, drawn from actual size of test pieces.

more of water, will probably crack when made up into brick shapes and set to dry; furthermore, they shrink too much. The cracking and shrinkage can generally be cured by the addition of sand, and some of the defective samples were treated in this way. The figures in the table show that the shrinkage was considerably reduced, and drying and burning difficulties were overcome.

Fig. 2 shows the amount of shrinkage the test pieces made of marine clay undergo from the moist to the burned condition.

When the test pieces were thoroughly air-dried, they were set in a down-draft, coal-fired kiln and burned for 32 hours. Standard pyrometric cones and a recording pyrometer were used to measure the heat treatment. It was found that cone 010 went down at about 1,700 on the pyrometer and cone 06 at 1,850 degrees Fahr. The character of the burned body at the different temperatures is indicated in the table under the headings, percentage of shrinkage, and absorption, the effect of the increasing heat being to make the test pieces smaller and denser in most cases. Vitrification has been accomplished in Nos. 693, 697, and 699 at the higher temperature, so that their capacity for taking up water has vanished, but the pieces show high shrinkage.

The tests indicate that the drying shrinkage of most of the clays is too high. When the percentage is eight or over, it is generally necessary to add sand for brick-making purposes, although it may not always be necessary for thinner ware, like drain tile.

The time occupied in burning has an effect on the character of the burned clay body. If the time of firing is prolonged, a denser body is produced at a given temperature than in a shorter period of firing, hence test kilns do not give quite the same results as commercial kilns.

In firing most of the red-burning surface clays of Ontario and Quebec, the finishing temperature of the kilns varies from 1,650 to 1,800 degrees Fahr. If the temperature of the kiln should reach higher than this, most of the upper portion of the bricks in a down-draft kiln would be softened and deformed.

These clays have what is known as a short range of vitrification, which means that the difference in temperature between vitrification and softening is small, and therefore vitrified products such as sewer pipe or paving brick cannot be made from them. The Champlain clays melt at a temperature of about 1,900 degrees Fahr.

It is necessary to add a word of caution with reference to the drying of these clays after they have been moulded into shape. Even with a liberal quantity of sand added, it is impossible, in most cases, to dry bricks made from the Champlain clay, safely, in an artificial dryer. The best practice hitherto has been to use the rack and pallet, outdoor system, and depend on the weather for drying. This method does not admit of a large output, as the rate of drying is slow compared to that in artificially heated dryers, but before building a dryer the clay should be submitted to ample tests to prove if it is capable of standing fast drying. The silts are better materials to work with as far as drying is concerned.

While sand must be used with the Champlain clays, in order to make them workable, it is possible to add too much. The effect of too much is to reduce the strength of the brick, as shown by the following results of tests made on mixtures of sand and clay in the laboratory. The sand and clay mixtures were made up into 3-inch cubes, and burned in the test kiln along with the other test pieces, to 1,750 degrees Fahr. The cubes were placed in the compression test machine, and the load applied until failure occurred.

	Compressive strength in lbs. per square inch
One part sand to three parts clay..................	2,314
One part sand to two parts clay..................	1,785
One part sand to one part clay..................	1,464

These tests show very clearly that the strength of the burned bricks is seriously impaired by the addition of too much sand, and that it is inadvisable to use more than one part of sand to two parts of clay for making building brick.

DESCRIPTION OF CLAY DEPOSITS

GRENVILLE COUNTY, ONT.

Edwardsburg Township.—A considerable part of the northeastern portion of this township is underlain by sand and stoneless clay; but the sand covering is generally too thick, except in the vicinity of the stream banks. Furthermore, the area underlain by clay is flat and drainage is sluggish, so that it would be difficult to keep the water out of clay pits during a great part of the working season. In the southern and western portions of the township the brick clay occurs only in small patches surrounded by stony or sandy ground.

Four samples from different localities were tested with the following results:—

Lab. No. 703 represents a small area about half a mile east of the town of Prescott. The deposit extends along the St. Lawrence river nearly to Windmill point, and is about a quarter of a mile wide. It has a steep bank facing the river from which it was possible to secure an average sample to a depth of 12 feet beginning at the surface, but the total depth of the deposit is 16 feet. It is the ordinary grey, massive, Champlain clay, working up very plastic and smooth when wet. Bricks made from it will dry in air, but crack if subjected to drying in an artificial dryer, even when the temperature of the dryer is as low as 125 degrees Fahr. The addition of sand helps to dry the brick, but does not make it able to stand high temperature drying. The shrinkage in drying is too high, but this can be reduced by adding sand. The burned colour is a good red and the body is hard and strong.

This clay is suitable for making drain tile as well as common brick.

Sample No. 704 was taken from a 4-foot section on Drummond island, the surface of which is all composed of this clay. It works up into a very stiff mass when ground and wet, burns to a dense red body, but has abnormally high shrinkage and is liable to check in firing. The addition of sand overcomes this to some extent, but the material is not recommended for the manufacture of burned clay products.

Lab. No. 721.—This sample was taken from the road ditch about 2 miles west of Spencerville, where the stoneless clay covers an area about one square mile in extent. There is another smaller patch of clay about 1½ mile south of this one, not far south of the village of Roebuck. These two patches of clay are the only ones for many miles around Spencerville. The sample represents only about 3 feet in depth from the surface, as it was impossible to secure one from a greater depth without boring or digging.

This clay works up very well, not being too stiff when wet. It burns to a deep red colour and hard body, and will make a good strong field drain tile as well as building brick. It required the addition of about 25 per cent of sand in order to reduce the shrinkage and help in drying.

Sample No. 706 was taken from a cut bank on the St. Lawrence river, in a bay just west of the canal entrance at Cardinal. The deposit is a small one, and has a thickness of 15 feet above the river level.

This clay works well in the raw state, and has a fairly low drying shrinkage. It burns to a good red sound body, and will make field drain tile as well as brick. It is not necessary to add sand to this clay in making field tile. This is the best of the clays examined in Edwardsburg township.

DUNDAS COUNTY, ONT.

Matilda Township.—The western part of this township is mostly underlain by marine, stoneless clay and sand, while stony clay covers most of the eastern and southern parts. The marine clay was found outcropping only at two places along the bank of the St. Lawrence, at points from one to two miles east of Iroquois village. The surface of the township is generally flat.

Sample No. 705 was taken by an auger from a clay deposit 1½ mile east of Hainsville, on lot 24, concession IV. The deposit consisted of seven and a half feet of stiff, marine, stoneless clay, and below the clay one foot of silty clay, underlain by fine gravel.

This clay has good working qualities, but has the usual high shrinkage and defective drying qualities, so that sand has to be added for brick-making purposes. It will make a good, strong, red, farm tile. There is an extensive area underlain by this kind of clay, and sand can be procured in the vicinity.

Williamsburg Township.—The surface of this township is covered mostly with stony clay; but there is a considerable area of swamp land, and some of the depressions which contain swamps may be underlain by marine clay. A few outcrops of stoneless clay are found along the St. Lawrence river, beginning about 2 miles east of Morrisburg. There is also a small area of stoneless clay in concessions V and VI, along the banks of a small stream flowing into the Nation river.

Sample No. 707 was taken from the bank of this stream, on lot 32, concession VI; it represents a bed about 4 feet in thickness. This clay is a rather indifferent material; its shrinkage is too high, and it is liable to crack in burning. It would require to be mixed with one-third its bulk in sand in order to make it workable, and there is no convenient source of sand.

The clay deposits along the St. Lawrence river are in places quite sandy and silty in the upper part, particularly near the old brickyard site, a short distance east of the Chrysler monument, and along the shore on lot 10, where sample No. 687 was collected. The upper part of the deposit at this point is flood-plain material deposited by the river before it had cut down to its present level. This material contains silt and fine sand as well as clay, hence it is more easily worked and dried than the ordinary, stiff, marine clay, and it has less shrinkage. Sample No. 687B represents the lower part of the bank at this point, and is the typical unmodified marine clay of the region. The material worked for brickmaking by Mr. Casselman, who formerly operated a plant a short distance north of this point, was similar to the upper part of the deposit exposed on the river bank which was sampled. A section on the creek bank, just south of the old brickyard, shows about 6 feet of yellowish silty clay in the upper part, and stiff plastic blue-grey clay below. A sand cover, varying from a few inches to 5 feet in thickness, covers most of the clay in the vicinity. This was a favourable point to carry on brickmaking as a good working mixture of the stiff bottom plastic clay, the upper silt, and the sand could be obtained. The clay pits were easily drained into the small creek which cut through the deposit and a supply of water could be obtained all through the summer.

The table of tests shows the results obtained from the different parts of the deposit, also from an average sample including both top and bottom of the bank. The great advantage of the silty clay in this locality lies in its having lower shrinkage and easier working and better drying qualities than the ordinary stiff grey clay.

Osnabruck Township.—The area underlain by stoneless clay in this township is comparatively small, and is confined to patches, principally in the southern part.

Sample No. 690 was procured from a clay area just north of the village of Farran Point, where a section of about 9 feet is exposed on the bank of a small creek. The sample represents an average of the deposit from top to bottom. This is a good brick material as it is not so stiff in working as most of the marine clays and has a reasonable shrinkage. It appears to contain a rather high percentage of lime, as the burned colour is pale and not a good red on account of the bleaching action which the lime exercises on the iron during firing. This clay is scarcely strong enough to make round tile, except the smaller sizes; the larger ones are apt to become deformed as they issue from the die of the machine.

Two patches of stoneless clay north of Dickinson Landing, along Doherty brook, contain brick and tile clays of a strong plastic character, but the deposits are mostly too shallow to admit of working. The clay is 15 feet thick in a narrow band at the Grand Trunk railway bridge, and this band of clay continues farther south along Hoople creek, but does not reach the banks of the St. Lawrence.

The steep bank along the St. Lawrence river between Woodlands and Dickinson Landing consists of dark grey silty clay overlain by yellow sand. Sample No. 691 was an average of about 10 feet of the silty clay. It is a stratified deposit, very greasy to the feel when wet, and represents a phase of sediment often found in the lower part of the Champlain clays. A reference to the table of tests shows that it takes less water for mixing and has a far lower drying shrinkage than the upper clay. Furthermore, this material contains such a high percentage of lime that it burns to a cream colour, which is in strong contrast to the prevailing red burned colour of the upper clay. A small brick plant operated in this locality about 70 years ago, but the upper red burning clay only appears to have been used at that time. The bottom silt deposit would make a very fine, cream-coloured, soft mud brick, but it is doubtful if sufficient space could be found for a brick plant there now.

There is a small area of clay and swamp land along the Raisin river, east of Lunenburg. A boring was made in this deposit on lot 2, concession IV, and the following materials were found from the surface downward:—

	ft. in.
Drab, non-calcareous, plastic clay, Lab. No. 695..	4 – 0
Peat..	1 – 6
Grey sand..	2 – 0
Highly calcareous, grey, silty clay, Lab. 696..	8 – 6

The bottom of the silt deposit was not reached as water came into the bore hole at the peat bed level, and finally the silt became so liquid that it could no longer be lifted in the boring auger.

Sample No. 695 is a good brick material; it works more easily, dries more readily, and shrinks less than the ordinary marine clay of the region. It burns to a good, sound, red body, and will make drain tile as well as brick.

Sample No. 696 is a typical silt; it contains very little real clay substance, and has not much plasticity, so that it was difficult to mould into shape for testing purposes. This material will stand fast drying without cracking, and

has a very small drying shrinkage. It burns to a light red colour, at the lower temperature, and to buff or cream colour at the higher heat. This material could scarcely be used alone for brickmaking, but it would be useful to mix with the upper clay. It resembles No. 691, but is not so plastic, and these are the only two examples of buff burning material encountered during the investigation.

Bricks were formerly made at the village of Aultsville, but none have been made there in recent years. A test was made from a sample of clay taken from one of the small clay areas in the vicinity of the village. The sample is number 689 in the table of tests, and appears to be the regular Champlain clay of the region.

Cornwall Township.—There are several irregular patches of stoneless clay in depressions between the morainal ridges of glacial drift in this township. Many of these depressions still contain swamps, and some of those that now contain stoneless clays may formerly have been swampy, before draining and cultivation began. Some of the clays of this area are more recent than the marine clays. They appear to have been washed down from the more elevated ground and carried into temporary ponds or swampy basins as the marine waters receded from the land. In this manner some of the clay sediment became mixed with peaty matter, and when this finely divided carbonaceous matter is intimately mixed with a stiff plastic clay it often causes trouble in burning, as such a clay is very liable to bloat and become cindery, especially if the temperature in the brick kiln is raised too rapidly. The carbonaceous clays are frequently proved to have defective properties in the raw state, such as excessive stickiness, bad drying qualities, and abnormally high shrinkages. Samples Nos. 693, 697, and 699 are examples of this kind; but such clays can be improved by the addition of a liberal quantity of sand, as indicated in the table, where the results of two clays thus treated are given below the corresponding number without the sand addition. These clays, however, are not recommended for use in the manufacture of burned clay products, unless nothing better can be procured in the district in which they are needed.

Sample No. 693 was taken from an auger hole bored in order to ascertain the depth of material in the small clay area adjacent to the quarries one mile north of Moulinette, for information with regard to the possibility of manufacturing portland cement at this point. The depth of the deposit is 15 feet, which includes 6 feet of brownish-grey upper stiff clay, and below, 9 feet of silty grey clay, resting on limestone bed-rock.

Sample No. 694 was taken from a hole bored in a field on the west side of the road, in lot 25, concession VI. This clay deposit, which lies in the valley of the Raisin river, was found to be 15 feet thick at the point tested, and is underlain by boulder clay. The deposit is stiff grey clay in the upper part and more silty below and the sample was an average of the whole depth. This clay would be suitable for the manufacture of field drain tile as well as brick, but for the latter purpose it needs a sand addition. Black River station on the New York and Ottawa railway is about one mile west of the deposit.

The best exposure of stoneless clay in the township, where the material can be inspected to the best advantage, is in the artificial cutting below the sluiceway at the eastern end of Sheek island. The upper and lower part of the bank, about 14 feet in all, was sampled at this point, but there is very little

difference in their qualities, either in the raw or burned state. Nor did the chemical analyses show much difference, so that the deposit can be regarded as homogeneous. The results of the physical tests obtained at this point are quoted in the table of tests, under Nos. 693 and 693a, and the chemical analysis is given on page 38. This clay deposit is unworkable on account of its position, but it was selected as a convenient place at which to sample a typical outcrop of the Champlain clay.

At the northwestern end of Sheek island, opposite the last house on the road, there is a section of dark grey stratified silt, sand, and clay in alternate layers, rising to a height of 12 feet above the river level, and overlain by 10 feet of sand. This is a very different material from the massive clay at the eastern end of the island, but it lies almost on the same level. They are both marine sediments.

GLEGARRY COUNTY, ONT.

Charlottenburg Township.—This township is similar in topography to Cornwall, and has the same kind of isolated stoneless clay deposits lying between the ridges of the glacial moraine. One of the largest of these clay patches, nearly a mile in width, occurs along the valley of Raisin river, southeast of Martintown. Sample No. 708, taken from a ditch one mile north of Macgillivray bridge, represents the clay in this locality and identifies it as the ordinary marine clay of the region.

Sample No. 700 was taken from the bank of a small creek flowing into Raisin river on lot 3, concession IV, one mile south of Williamstown, where 5 feet of clay is exposed above water level, overlain by 3 feet of sandy loam. If this clay were mixed with an equal proportion of the sandy loam, it would work well for brick or tile.

There is quite a large area between Williamstown and Lancaster in which clay occurs beneath a covering of variable thickness of fine sand or sandy loam. The land, however, is quite flat, and drainage of clay pits would be difficult in any part of it except close to Raisin river.

Sample No. 697 was taken by an auger boring from the bank of Crays creek in concession I. This clay is defective in working and drying qualities, and the shrinkage is excessive, hence it is not recommended for the manufacture of clay products.

Lancaster Township.—Most of the southern portion of this township is flat land, with sand, sandy loam, and sometimes clay as the surface material. A large part of it has stoneless clay as subsoil, with sand or loam as a covering of variable depth. North of the flat, sandy area, the topography is the same as that of Charlottenburg, in which there are a few long narrow patches of stoneless clay along stream valleys and between some of the ridges of glacial drift.

Sample No. 709 was an average of the material thrown out while digging a well in a field near the road, one-fourth of a mile north of North Lancaster station on the Canadian Pacific railway, on lot 24, concession IV. The well was probably dug to a depth of 6 feet or more, and among the ordinary grey clay thrown out of the excavation, some reddish clay was noticed. A layer, or band of red clay is occasionally seen in the Champlain clay, but it rarely occurs in the region so far examined.

This is a good brick and tile clay, it works easily and its shrinkage is not too large. It burns to a good red colour, with a hard, sound body, and is recommended for the manufacture of field drain tile. The only drawback to working this clay is the lack of drainage necessary to keep the excavation from being flooded.

Sample No. 698 was taken from the bank of a small creek on lot 30 in concession V. Sand overlies the clay a short distance from the banks of the creek. This is one of the good brick and tile clays.

Sample No. 713 was taken from the bank of a creek on lot 10 in concession VI, three-fourths of a mile south of Dalhousie station. This clay works easily, has good drying qualities, and the shrinkages are not unduly large. It is recommended for the manufacture of red building brick or field drain tile. The clay is only 3 feet thick at this point, and is underlain by sand; but there may be more clay below the sand.

Sample No. 714 was collected on the bank of a creek at the railway bridge, half a mile east of Bridge End station, on the Canadian Pacific line. A thickness of seven feet is exposed showing stratified clay, but one of the layers, about two inches thick, is a fine-grained, reddish, highly plastic clay. An average sample of this deposit, with the proper amount of sand in addition, would be suitable for making brick and drain tile. The drainage in this vicinity is good, and wood for fuel can be procured in the district.

VAUDREUIL-SOULANGES, QUE.

The portions of Vaudreuil and Soulanges counties which come within the limits of the map sheets are mostly flat plains of Champlain clay, but a layer of sand of varying thickness covers the clay in some places.

The clay deposit is so widespread and its character so uniform, in this district, that a few examples will suffice to give general information regarding the whole area.

Sample No. 715 was collected on the bank of Quinchien creek at a point just south of St. Lazare station on the Canadian Pacific railway. The little creek has cut into the clay plain to a depth of about 25 feet (Plate II), but only 8 feet of the top part of the bank was included in the sample. There is an 18-inch layer of sandy loam overlying the clay, and a separate sample of this was collected. It is No. 715A on the list of tests.

No. 715 is the ordinary grey Champlain clay which is so abundant in this region. It is grey in colour, very smooth and plastic when wet, but has good working qualities, not being too stiff. It must be dried slowly in order to avoid cracking, and it has a high shrinkage from the wet to the dry state. It burns to a hard body with a good red colour.

The sandy loam, No. 715A, contains enough clay substance to enable it to be moulded into shape, but it is very low in plasticity, and forms a punky, wet body which is liable to get out of shape when dumped from the moulds. It can be dried quickly without cracking, and its shrinkage is low. It burns to a porous red body of no great strength.

While neither of these materials is good when used alone, a mixture of equal parts of each will make an excellent red brick or field drain tile.

Sample No. 716 was collected from a high clay bank beside the Canadian Pacific Railway line, at a point 2½ miles west of the village of Vaudreuil. The river Quinchien flows at the base of this bank, and sample No. 716B was taken from the bank of that stream. Three different kinds of clay are represented there: the upper part of the high bank, the lower part of the bank, and, below, the clay along the base of the high bank into which the stream has cut down to a depth of 7 feet (Plate IX).

No. 716 is an average sample of the upper 15 feet of the high bank. It is a stiff, plastic, smooth, brownish-grey clay, similar in all respects to that at St. Lazare.

No. 716A is an average sample of 10 feet of the lower part of the bank. It differs in appearance from the upper clay, being bluish-grey in colour, and showing banding or stratification, while the upper clay is massive, and shows no banding. This lower clay is not so stiff as the upper, hence it works easier. It is also difficult to dry fast without cracking, but the shrinkage in drying and burning is not so great as in the upper clay. The burned body is not quite so hard as that of the upper clay, and the red colour is not quite so strong.

No. 716B, the material from the bank of the stream, is stratified, yellowish sandy clay, carrying numerous particles of mica. Some of the layers are more sandy than others, but the whole works up when wet into a fairly plastic mass with good working qualities. This clay will stand fast drying, and its shrinkage on drying is much less than the Champlain clays in the high bank. It burns to a deep red colour and strong body. This is the best brick clay so far found in the region, and it would also be suitable for the manufacture of hollow building block or fireproofing.

The site at which these clays occur has many advantages for a plant designed to make brick and tile. There is an abundance and variety of clay, easily worked from excavations that can be kept well drained. Sand for moulding purposes or for mixing with the clay occurs on top of the high bank, and a water supply can be obtained throughout the summer. There is convenient railway transportation, and the highways in the vicinity are well maintained. so that field drain tile and building material made at this point could be readily distributed.

The chemical analysis of samples Nos. 716 and 716A is given on page 38.

ISLE PERROT, QUE.

There is a very heavy deposit of Champlain clay on parts of Isle Perrot. The high bank along the south shore of the island is composed of this material, and the deposit reaches to the north shore also. No samples were taken from this locality, but the clay will be found similar to that of Beauharnois county, of which tests are given below.

There is an abundant forest growth on the higher and more rugged parts of the island, so that a plant making brick or tile there would be assured of a good fuel supply.

BEAUHARNOIS COUNTY, QUE.

The greater part of Beauharnois county is flat land, underlain by Champlain clay of precisely the same character as the clay lands north of the St.

Lawrence in Soulanges-Vaudreuil. The best places at which to examine the clays are along the banks of the St. Lawrence river, or on the clay terrace adjacent to it.

Sample No. 719 was collected from a clay bank at the roadside near Maple Grove station on the New York Central railway. The terrace front from which this clay was taken continues westward through the villages of Beauharnois and Melocheville.

This clay has a high shrinkage, and would require the addition of one-third of its weight in sand for the manufacture of brick or tile.

Sample No. 720 was taken from the clay terrace one mile west of the village of Beauharnois. It is an average of 7 feet of the clay along a farm road leading to the fields on top of the terrace. This clay is highly plastic, smooth Champlain clay, and is in no way different from No. 719. The chemical analysis of the clay is given on page 38.

There is no sand available in the clay area from which these samples were taken, but it could probably be obtained from the shallow water along the shore of the river. Brick and tile could be made from the clay anywhere in this vicinity, provided sand for mixing and moulding can be procured conveniently.

Sample No. 718 was obtained from the steep bank on the St. Lawrence river, at a point midway between Melocheville and St. Timothée. It is an average of 15 feet of the clay from the surface downward, and is the same kind of clay as Nos. 719 and 720.

Sample No. 717 was an average of 10 feet in depth from the bank of the south channel of the St. Lawrence, near the east end of DeSalaberry island. It behaves similarly to the above clays in the raw state, but its shrinkage after firing is greater.

Sample No. 712 was taken from an irrigation ditch one mile north of St. Louis de Gonzague. About a foot of peat overlies the clay in this vicinity. This is the ordinary Champlain clay of the region. There is no sand available in this vicinity.

Sample No. 711 was taken from a hole bored with an auger beside a drainage ditch on the north side of St. Louis river, about two miles northwest of St. Louis de Gonzague. The following materials were obtained:—

No. 711A.	Fine grey silty sand with a little clay..	5 ft.
No. 711.	Stiff browning Champlain clay, containing fossil shells..	2 ft.
	Bluish-grey silty clay to boulder clay at bottom..	6 ft.

The upper material, No. 711A, contains a good deal of fine grit and is not so smooth and plastic as the ordinary Champlain clay. It has enough plasticity to enable it to be moulded into shape. It dries readily, and its drying shrinkage is within practical limits. It burns to a fine red colour and strong body, and would make very good building brick by the soft mud process. It is a much better brick material than the ordinary Champlain clay.

No. 711 is an average of the lower 8 feet of the hole. This is the ordinary smooth, plastic Champlain clay, with the usual high shrinkage and poor drying qualities. By mixing two parts of the top clay No. 711A to one part of the lower stiff clay, a mixture could be secured for making good building brick and field drain tile.

Sample No. 710 was taken from a drainage ditch at the roadside, about 4 miles northeast of St. Barbe. This material is mostly silt, but contains enough clay to enable it to be worked for brickmaking. It dries readily and its shrinkage on drying is low. It burns to a good deep red colour and strong body. This material is recommended for brickmaking on account of its good working and drying qualities and its character and colour when burned. This kind of material is widespread in this part of the country, and appears to be a silt deposit laid over the land by flood water from lake St. Francis. It is more suitable for brickmaking than the highly plastic Champlain clay, but it is doubtful if it would make drain tile on account of its lack of plasticity.

BUILDING STONES

Stone for building purposes can be obtained at a few places in the district; but on account of the heavy mantle of drift material which covers most of the area, the outcrops of rock are not very numerous. The materials obtainable are limestone or dolomite, and sandstone. The principal quarries, which have been worked from time to time, have been described by Dr. Parks in his report on the Building Stones of Canada.[1]

Sandstones

Outcrops of sandstone of Potsdam age are to be found along the river front in Beauharnois county, between Melocheville and Beauharnois, and a number of quarries have been opened up. Outcrops of similar material are also to be found at Cascades Point, and at a number of places on Isle Perrot, Vaudreuil county.

BEAUHARNOIS COUNTY, QUE.

The most important outcrop in this county occurs along the river front between the villages of Melocheville and Beauharnois. The rock is exposed almost continuously between these two places. Several quarries have been opened on this outcrop in the vicinity of Melocheville, the principal one being situated at the eastern limits of the village. This quarry is operated at the present time, and the material excavated is crushed in a mill on the bank of the canal, and the sand produced shipped to Montreal for use in steel foundries and in glass making. The quarry has a 10-foot face, of fairly white, clean sandstone, in beds approximately 18 inches thick. It would be hard to obtain blocks of large dimensions from this quarry, but considerable rubble material could be obtained.

In the bed of the St. Louis river, on the western outskirts of the town of Beauharnois, a quarry is being operated by Wm. Robert, from which blocks up to 4 feet in thickness could be obtained. The material in this quarry is creamy white, and of very even texture (Plate XVIII).

On the north side of the river, at Cascades Point, there is an abandoned sandstone quarry from which considerable material has been excavated from time to time, both for building purposes and for the manufacture of steel foundry sand. The rock is harder than similar material on the south side of the river. The beds average about one foot in thickness.

[1] Building Stones of Canada, Vols. I and III, Mines Branch, Department of Mines, Ottawa.

There are a number of places on Isle Perrot where outcrops of sandstone are to be seen. A large quarry has been operated in past years at Isle Perrot Nord, southeast of Ste. Anne de Bellevue. The rock in the quarry is reddish coloured, coarse-grained sandstone, with well defined cross bedding. The whole exposure shows lamination. Quarry buildings, derricks, and loading bins are still in place. An average section of the face of this quarry is as follows:—

12 inches..	..Coarse-grained, reddish sandstone
12 "	....Coarse, loosely cemented sandstone, with rounded quartz grains up to ⅛″ diameter
36 "	....Coarse-grained, red sandstone
42 "	....Coarse-grained, reddish sandstone
3 "	....Parting bed of weathered shale
48 "	....Coarse-grained, reddish sandstone
153 inches..	..or 12 feet 9 inches face

At the northeastern corner of the island another extensive outcrop of sandstone occurs, but only small quantities of rock have been excavated from two or three small quarries, for use locally.

Sandstone from these localities is suitable for use in building construction; and the material can probably be obtained in sufficient quantity to quarry on a large scale. Crushing tests were made on 2-inch cylinders cut by a diamond drill from blocks taken from the quarry of Wm. Robert at Beauharnois. The results obtained from these will apply to all the sandstone of the district.

Crushing Test of Sandstone

Test No.	Size of specimen	Crushing strength Total	Per sq. inch
1	3″ x 2″	60,750 lbs.	19,337 lbs.
2	3″ x 2″	87,400 lbs.	24,637 lbs.

Average strength per sq. in. 21,987 lbs.

This crushing strength compares very favourably with the crushing strength of limestone tested by Dr. Parks, and obtained from the following localities:—

	Crushing strength lbs. per sq. in.
Mille Roches quarries..	22,356
Sheek Island quarry..	21,693

Limestones and Dolomites

Limestones and dolomites have been quarried at a number of localities in the district, and considerable material has been excavated for building purposes. There are only a few places, however, from which blocks of large dimensions can be obtained, since most of the beds are thin, and badly jointed. The more important outcrops and quarries are briefly described in the following pages.

GRENVILLE COUNTY, ONT.

Augusta Township.—Bed-rock outcrops are frequent in the narrow strip of this township which appears on the Morrisburg map sheet. The rock is mostly dolomite of Beekmantown age, and quarries have been opened in several places on the exposures.

In the town of Prescott there is a quarry in which an exposure of 9 feet of dark, blue-grey weathering dolomite can be seen. The beds are thin, from

2 inches to 8 inches in thickness. The rock is flat lying, and is overlain by 18 inches of sandy boulder clay. All the beds are coarsely crystalline. There is another exposure of the same outcrop in a quarry opened on the street. Both quarries have supplied stone for road making purposes, and one or two houses in the town have been built with it, but the beds are hardly thick enough for good building stone.

There is also a considerable area of bed-rock exposed north of the railway station, lying parallel with the tracks.

Farther north there are a number of other exposures, but practically no quarrying work has been done on any of them, except in the vicinity of Domville, where a small amount of work has been done on the east side of the road about one-fourth of a mile to the north of the village. A face of 4 feet is exposed at this quarry. The top beds are thin and badly weathered, and carry numerous calcite patches. The bed in the bottom is harder and not weathered. The rock in the lower bed is a buff-coloured, compact, fine-grained dolomite. On the road east of the quarry and on the same outcrop, there is a well-marked escarpment, in some places 10 feet high.

Near the village of Roebuck beds of flat lying dolomite are exposed for about half a mile in the bed of the creek, but practically no rock has been excavated.

To the north, the mantle of drift material seems to become heavier, and no rock exposures of any importance were noted.

Edwardsburg Township.—In the western and northern part of this township, included in the Morrisburg map sheet, rock outcrops are to be seen at a number of localities. The drift covering appears to be thin and in most cases the rock surfaces exposed are of considerable extent. To the east and southeast of this township the mantle of drift or marine sediments becomes thicker and, consequently, rock exposures are rare.

One of the most extensive quarries in the township has been operated from time to time at Windmill point, south of the river road and just east of the old windmill. In this quarry a section of nearly 32 feet has been exposed. The quarry has been worked out to the water level of the river and back as far as the road. The following is a typical section seen in this quarry:—

Section in Windmill Point Quarry

6′ – 0″..In this section beds are very weathered and thin—from 2″ to 6″, but appear to be identical with the reddish-grey, crystalline bed directly below.	1′ – 8″..Thin-bedded, reddish-grey, shaly dolomite.
3′ – 10″..Reddish-grey, crystalline dolomite.	3′ – 9″..Dark, reddish-grey beds, 8″ to 12″ thick.
1′ – 0″..Dark red, soft bed, showing iron stains.	1′ – 3″..Reddish-grey bed.
4′ – 1″..Reddish-grey beds, with the top 10″ a light, reddish-grey, finer in texture.	3′ – 6″..Grey dolomite beds.
1″..Seam of fine-grained, blue dolomite.	1′ – 0″..Reddish-grey bed.
2′ – 3″..Laminated beds. These show up best on weathered surfaces.	3′ – 6″..Grey, crystalline dolomite, bluish in places. Beds 8″ to 12″, with occasional vertical calcite seams.
	St. Lawrence river water level. Total section 31′ – 11″.

To the north of Windmill point, along the Ottawa-Prescott highway, there is an extensive exposure in the third concession. A group of quarries on this ridge, on lots 23 to 26, had been worked intermittently on a small scale. The rock is brown in colour, with a yellowish cast, and is fine-grained and crystalline. On lots 34 and 35, concession V, there is a bed-rock outcrop with beds of flat lying, greyish-blue dolomite, fine in texture. A small amount of rock has been quarried at this locality, for local use.

The bed-rock outcrops shown to the north of these are of a very similar nature. On most of them there has been little or no work done, and their character could not be determined.

In the southeastern part of the township there is a quarry of considerable extent on lots 11 and 12, con. I, owned by Mr. McLaughlin. The quarry is filled with water at the present time, but is said to be 15 feet deep in places. Above the water level there is a face of 28 feet exposed (Plate XXVIII). The following section is typical of the upper beds of this quarry:—

Section in Quarry One Mile West of Cardinal

27′ – 7″	..Top soil, 1 foot.
26′ – 7″	..Soil with rock fragments partly in original position, 3 feet.
23′ – 7″	..Thick-bedded dolomite, filled with chert which runs parallel to bedding, and across it, with partings of oolitic dolomite, 3 feet.
20′ – 7″	..Thick-bedded and thin-bedded brownish weathering dolomite, with thin limey partings, 2′ – 6″.
18′ – 1″	..Covered interval, 4 feet.
14′ – 1″	..Thick-bedded layer of grey dolomite like that at water's edge; beds 8″ to 10″ thick, with a few calcite inclusions, 1′ – 6″ thick.
7′ – 1″	..Thinner bedded, grey dolomite, 4″ to 6″ thick, with many faulted laminae beds separated by very thin shaly partings; calcite concretions scarcer in these beds, 5′ – 6″.
6′ – 10″	..Dolomitic parting, 3″.
2′ – 2″	..Thick-bedded dolomite as below but thinner partings than below, 4′ – 8″.
0′	..Heavy-bedded dolomite, with calcite-filled caverns; beds about 10″ thick, 2′ – 2″; water's edge.
	Water 14′ to 15′ deep, with rock to bottom.

About half a mile to the north of this quarry the same beds are exposed on both sides of the railway tracks, and half a mile farther north another outcrop is to be seen. In the latter exposure the beds are thin, and weathered, 12 inches being the thickest bed noted. The rock is mostly grey to dark grey dolomite, with calcite inclusions in places.

DUNDAS COUNTY, ONT.

Matilda Township.—With the exception of a few isolated exposures in the southwestern part of the township, rock outcrops are practically absent. The outcrops to be seen are all of small extent and, with one exception, have not been worked, or have had only small amounts of material excavated.

On the north half of lot 35, con. I, on the property of Wm. Saver, a quarry has been opened and considerable rock excavated. The material exposed is mostly grey to dark grey dolomite, in beds up to 18 inches in thickness. Some of the first material quarried from this property was employed in the building of the original canal at Cardinal. A good face and quarry could be opened on this property.

The same ledge is exposed about one-fourth of a mile farther north, where a small quarry has been opened, and the material used for local construction. This quarry is owned by John Bewley.

Two miles east of the station at Cardinal, on the north side of the railway, a small excavation on an outcrop shows a 6-foot section of thin bands of blue, shaly dolomite, with about 18 inches of grey weathering dolomite on top.

Williamsburg Township.—There are no rock exposures along the river front in this township, but back from the river there are occasional outcrops.

Two exposures were seen, in the neighbourhood of Bouckhill and on lots 34 and 35, con. VI. At the latter place there is an exposure of limestone of considerable extent, but, in most places, the beds are thin. The thickest noted was only 6 inches. The material is coarsely crystalline and the exposure is worthy of note inasmuch as it is one of the few occurrences in the district of high calcium limestone. The following analyses[1] from material taken from outcrops just north of this locality will give an idea of its composition:—

	No. 1	No. 2
Insol	10.8	5.61
Fe_2O_3	0·72	0·70
Al_2O_3	0·48	0·10
$CaCO_3$	80·66	89·59
$MgCO_3$	7·58	3·78

No. 1: Lots 31 and 32, con. VII, Williamsburg tp., Dundas county, Ontario.
No. 2: Lot 19, con. VII, Williamsburg tp., Dundas county, Ontario.

At Bouckhill there are two exposures of the same outcrop, about a mile apart, and small quantities of material have from time to time been excavated. The beds are thin, and the material is very friable.

STORMONT COUNTY, ONT.

Osnabruck Township.—There is only one quarry in this township, situated over five miles back from the river front, on lot 27, con. V. Here, a quarry, over an acre in extent, has been opened up to an average depth of 3 feet. The beds exposed dip to the south at an angle of about 2 degrees. At the top the beds are thin and badly weathered. The bottom beds might yield material one foot in thickness. There are some shaly layers interbedded with the limestone. It is stated that the stone for the locks at Farran Point was taken from this quarry.

Cornwall Township.—Although rock outcrops in this township are not numerous, they are of considerable economic importance. Several extensive quarries have been operated in past years, and a large amount of heavy dimension stone has been taken out, principally for canal construction. The main group of quarries is situated to the north of the town of Mille Roches, Ont.

These quarries have not been operated for a number of years, and are filled with water at the present time. The openings are all in the low land of the district, and the overburden which has been removed varied from 2 to 16 feet. Extending these quarries would involve the removal of a heavy amount of covering. The beds in these quarries are very heavy, and blocks of nearly any dimensions required could be obtained. At the present time there is a large amount of broken stone at the quarries that would be suitable either for use

[1] Mines Branch, Summary Report, 1916, pp. 29-30, samples 38 and 39.

in concrete or for the manufacture of cement. A sample of this loose material was analysed, with the following result[1]:—

	Per cent
Insol	2·80
Fe_2O_3	Tr.
Al_2O_3	0·20
$CaCO_3$	94·58
$MgCO_3$	1·51

This is a high calcium limestone, and its suitability for use in the manufacture of cement is mentioned elsewhere in this report.

To the north of the town of Cornwall are a series of quarries, opened up on a low rock escarpment rising about 10 feet above the surrounding district. The quarries are situated on lots 4, 5, and 6, con. V, Cornwall tp., and the owners are Messrs. Clark, Cameron, Friend and McLeod.

A large amount of stone has been removed from these quarries, and there is possibly a big tonnage still available. The beds are very massive, the top bed varying from 38 inches to 69 inches thick, with beds beneath quite as thick. The rock is a dark, blackish-grey, massive limestone, very dense in texture, with a large number of calcite streaks and many minute shaly partings.

The overburden at the quarries varies from one foot to ten feet, becoming thicker to the north. The beds have a slight dip to the north.

Rock from these quarries was used in the construction of the Cornwall canal.

Half a mile to the south of the quarries, there are three or four small rock outcrops, but the possibility of opening up quarries on these exposures is very slight, on account of the difficulty of proper drainage.

About 9 miles north of Cornwall there is a large area of land in which rock outcrops are numerous and over which the drift covering is very thin. To the north of Sandfield Mills, bed-rock is exposed in the bed of the north branch of Raisin river, practically continuously, for a distance of 1½ mile. Most of the beds noted were thin.

GLENGARRY COUNTY, ONT.

Charlottenburg Township.—No quarry work of any great extent has been carried on in this township, and with the exception of the small quarry 1¼ mile southeast of Summerstown station, no outcrops were noted nearer to the river front than 6 miles.

The quarry to the southeast of Summerstown station was not visited, but R. H. Picher[2] in his report on the road materials of the district described it as follows:—

> Chazy limestone formation. Limestone is light grey. Slightly banded, medium to coarse-grained, thick-bedded, but splitting up easily into thin layers. Beds have a gentle dip northwest. The stone taken out of an old quarry, 250 cubic yards in size, was used by the Grand Trunk Company over 50 years ago, for bridges and culverts. There are no outcrops, and the overburden varies from a few inches to 2 feet in thickness. A few thousand cubic yards could be taken out in a dry season, assuming an average depth of 1 yard. Owner: D. Cattanach, Summerstown station, R.R. 1.

In the northern part of the township there are several minor quarries, from which small dimension material has been obtained from time to time, for local use; but it is highly improbable that any of these exposures will furnish a large tonnage in the future.

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[1] Mines Branch, Summary Report, 1916.
[2] Mines Branch, Dept. of Mines, Bulletin No. 32, 1920, p. 17.

Lancaster Township.—With the exception of two small rock outcrops shown on the map, in the neighbourhood of Glenevis, in the northern part of the township, there are no quarries or rock exposures from which stone of any description can be obtained.

SOULANGES COUNTY, QUE.

In this county, the bed-rock outcrops are confined to the area lying between the St. Lawrence river and the Delisle river, and extending laterally from Coteau Landing and Coteau-du-lac, Que. In this area four small outcrops or quarries have been operated spasmodically at different times, and stone for local use excavated. The rock exposed is all highly magnesian limestone of Beekmantown age, and it is not likely that any great tonnage of material suitable for heavy construction work could be obtained, owing to difficulty in draining and the heavy overburden which in places would have to be removed. One quarry situated one-fourth of a mile to the east of the railway bridge and half a mile to the north of the canal road was sampled and analysed with the following result:—

Insol.	6·90
Fe_2O_3.	1·14
Al_2O_3.	0·26
$CaCO_3$.	53·03
$MgCO_3$.	38·58

This quarry is idle at the present time but has been operated recently for road material. Blocks up to 2 feet in thickness could be obtained from it.

VAUDREUIL COUNTY, QUE.

In this county no outcrops of limestone or dolomite were encountered in the area mapped.[1]

BEAUHARNOIS COUNTY, QUE.

The beds of limestone found in this county are all of Beekmantown age. A noticeable topographic feature of the district is, that wherever boulder clay has been encountered, bed-rock was, in nearly all cases, only a short distance below the surface. A number of outcrops are being operated, or have been quarried recently to obtain rock for local use.

To the north of the railway station at Bellerive, on DeSalaberry island, a quarry, owned by George Lapierre, is being operated at the present time for road material. The lower beds only are being used for this purpose, as the upper beds are from 4 to 8 feet in thickness—very massive and compact. The beds in the lower strata vary from six inches to one foot. The rock is very hard and brittle, breaks with a conchoidal fracture, and has been found to be a difficult rock to chisel and dress for building purposes. In some of the lower beds small crystals of iron pyrites are noticed, and these have, in cases, become decomposed with the formation of gypsum crystals in the vugs and cavities. The presence of these iron pyrites crystals might be injurious if the material were utilized as the coarse aggregate for concrete. The overburden is not very thick, and there is a large amount of material available from this and the other quarries in the neighbourhood.

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[1] In that part of the island of Montreal which is shown on the Valleyfield sheet, the rock outcrops were not examined, but descriptions of these exposures are given in the Stansfield report previously referred to, as well as in Dr. Parks' report on the Building Stones of the Province of Quebec.

To the east of these quarries, about one mile, there is an abandoned quarry in which a face of 10 feet was formerly worked. The quarry is filled with water at the present time, and the beds exposed above the water are all thin.

A typical quarry, in Beekmantown formation, of this county is to be seen about half a mile to the west of St. Timothée station, on the New York Central and Hudson River railway. A total section of 13½ feet is exposed. The following is an average section:—

6"	Fairly coarse-grained, grey dolomite (fossiliferous).
16"	Medium-grained, grey dolomite (fossiliferous).
8"	Coarse-grained, grey dolomite.
18"	Medium-grained, grey dolomite, very wavy structure. Numerous cavities filled with calcite and occasional quartz crystals.
8"	Medium-grained, grey dolomite, shaly structure.
18"	Medium-grained, grey dolomite, banded structure with cavities filled with crystalline calcite.
9"	Fine-grained, compact, grey dolomite.
1"	Chert seam.
10"	Medium-grained, light grey dolomite, wavy blended structure.
21"	Coarse, crystalline, dark grey dolomite.
16"	Coarse-grained, grey dolomite, sandy texture.
12"	Medium-grained, grey dolomite, occasional banded structure.
20"	Medium-grained, grey dolomite (bluish) compact.
163"	13½ ft.

Another quarry, in material similar to the one just described, has been operated on the north side of the Beauharnois canal, about 1½ mile east of the village of St. Timothée, Que. The quarry at the present time is nearly filled with water.

About four miles to the south and west of Valleyfield there is a group of rock exposures from which small quantities of rock have been taken. In one of the exposures a 3-foot section of fine-grained grey dolomite occurs overlying a shaly parting bed one-half inch to one inch in thickness. The beds exposed were from 8 inches to 13 inches thick.

Two miles to the east of the town of Beauharnois dolomite has been quarried from a series of small quarries on the point at Maple Grove. One quarry owned by Francois Hebert, Maple Grove, Que., is being operated at the present time for road material. It was from this quarry that the large sample for the concrete test, referred to in another section of this report, was obtained. The overburden in the vicinity of these exposures is boulder clay, from one to three feet thick. There is a section of 3½ feet exposed at the largest quarry. The rock is fine-grained and compact, with a rather flinty fracture, and on this account is hard to chisel and dress. An analysis of this stone proves it to be highly magnesian.[1]

	Per cent	
Insoluble matter	5·10	
Ferric oxide and alumina	6·36	
Calcium oxide	29·35	equivalent to 52·41% carbonate of lime
Magnesium oxide	15·96	equivalent to 33·4% carbonate of magnesia

Two-inch cylinders were drilled in the laboratory from blocks taken from this quarry, and tested for compressive strength, with the following results:—

No. 1	17,826	lbs. per square inch
No. 2	21,454	" "
No. 3	21,900	" "
Average	20,393	" "

Compare these results with the results obtained from the sandstone, and noted on page 52 of this report.

Other small exposures, similar to those described above, are noted on the map.

[1] Mines Branch report No. 279, 1914, p. 107, Dr. Parks.

CHATEAUGUAY COUNTY, QUE.

In this county there is a prominent escarpment of rock, outcropping almost continuously from Bellevue to Woodlands, and thence southeasterly to the village of Chateauguay. Quarries have been opened up on this exposure in several localities, the principal one being at the most easterly end of the escarpment about half a mile west of Chateauguay village. In this quarry there are 17 feet exposed, and the following section is typical:—

6" to 24"... .Overburden of boulder clay.
24"... .Fine-grained, banded dolomite.
7"... .Fine-grained, grey dolomite.
12"... .Coarse-grained, dark grey dolomite, with shaly bands.
4"... .Fine-grained, shaly dolomite.
14"... .Medium-grained, grey dolomite, banded structure.
8"... .Medium-grained, grey dolomite, banded structure.
½"... .Shaly parting plane.
3"... .Fine-grained, grey dolomite.
5"... .Medium-grained, dark grey dolomite, with shaly bands.
24"... .Fine-grained, mottled dolomite.
31"... .Medium-grained, blue-grey dolomite, numerous bedding planes.
3"... .Shale band with mud cracks.
2"... .Coarse-grained, dark blue dolomite.
15"... .Fine-grained, blue dolomite, with numerous joint planes.
3"... .Medium-grained, shaly dolomite.
7"... .Fine-grained, dark grey, banded dolomite.
9"... .Fine-grained, compact, blue dolomite.
6"... .Dark grey, fine-grained dolomite.
12"... .Medium-grained, grey dolomite, banded structure.
14"... .Fine-grained, compact, blue dolomite.

There is considerable stone available in this area, with only a small amount of overburden. (Plate XXX).

LAPRAIRIE COUNTY, QUE.

In the small part of this county included in the Valleyfield sheet there is one quarry, in Chazy formation, about one mile to the southwest of Primeau station, on the west side of the road.

In this quarry there is a face of over 7 feet exposed. The following is a representative section:—

24"... .Coarsely crystalline, blue limestone, fossiliferous.
21"... .Coarsely crystalline, blue limestone, sparsely fossiliferous.
8"... .Medium-grained, blue limestone, sparsely fossiliferous.
5"... .Weathered band of sandy clay (residual?) probably due to the weathering of a band of shale.
30"... .Medium-grained, blue limestone with few fossils.

In the top four feet, the beds show vertical joint planes, along which pronounced weathering has taken place. The quarry is being worked at the present time to supply material for road work in the district.

CEMENT MAKING MATERIALS

Clay and Limestone

The raw materials used in the manufacture of portland cement are limestone and clay, the mixture being generally in the proportion of three parts limestone to one part clay.

A clay deposit suitable for the manufacture of cement can be more easily obtained than a suitable limestone.

The most desirable site on which a cement plant can be built is one at which both limestone and clay are within easy reach. Failing to obtain clay and limestone deposits side by side, cement plants are generally built at the limestone deposit, and the clay, which is the smaller portion of the mixture, is brought from a distant point. Other considerations, however, such as a convenient fuel supply, sometimes modify the above procedure. A cement plant near Medicine Hat, for example, has abundance of clay in its vicinity, but no

limestone, the latter being obtained at a point 250 miles farther west; but the inducement of a cheap supply of natural gas for burning offsets the long haul of the limestone.

The large cement plants at Hull, Que., near the city of Ottawa, and at Maisonneuve, near Montreal, draw their supplies of raw materials from their immediate vicinity, but fuel must be brought from Nova Scotia or Pennsylvania.

The area examined contains limestones and clays similar to those used in the Ottawa and Montreal plants, but the limestones, as a rule, are not exposed to the same extent, for advantageous working.

One of the requirements in a limestone for cement purposes is that the amount of magnesian carbonate it contains must be low.

The limestone in the old quarries north of Mille Roches, in the township of Cornwall, Stormont county, Ontario, would be suitable for cement purposes according to the chemical analysis given on page 56, but it would be impossible to quarry it extensively on account of the thick overburden of glacial drift which would have to be removed. A good deal of limestone could now be obtained at the locality without an excessive overburden, but ultimately expensive stripping would be necessary. There is a deposit of clay in the valley of a small stream immediately north of the limestone quarries. The deposit is not extensive, and its depth, as ascertained by boring, is not more than 15 feet. There is, however, a more extensive clay deposit about a mile east of the quarries, as shown on the map.

Limestone outcrops in a low escarpment on lots 4, 5, and 6 in the fourth concession of the township of Cornwall, in Stormont county, at a point 3 miles north of the town of Cornwall. The beds are similar to those mentioned above, and probably contain as high a percentage of calcium, but no chemical analysis was made of samples from this locality. A narrow depression immediately to the south of the limestone outcrops contains a clay suitable for cement purposes.

With the exception of the two outcrops above mentioned there do not appear to be any limestone deposits suitable for cement purposes within the boundaries of the region examined. All the other limestones contain too high a percentage of magnesia, and consequently, are not suitable for cement-making purposes.

SANDS AND GRAVELS

A general description of the sands and gravels has been given in a previous chapter, hence their economic importance only will be dealt with here.

Sands

The sand areas, like the marine stoneless clays, are confined to the lower elevations of the region. In the township of Williamsburg, in Dundas county, the sand areas are close to the St. Lawrence river, on terraces standing at elevations of 225 to 250 feet. The sands on the narrow terrace bordering the river between Farran Point and Dickinson Landing, in Stormont county, are from 200 to 225 feet in elevation, while the largest areas of sand in the region are in Glengarry county, lying on plains about 175 feet above sea level.

The position of these sands and the slope of their surface seem to indicate that they were laid down by the St. Lawrence river, when it stood at a higher elevation. The sand from deposits of this nature, in this district, is fine in

texture, having an average fineness of about 80, and the greater part consists of well rounded grains of quartz. The greater part of the limestone grains which one would naturally expect to find in sands of this district, has been removed.

The numerous beaches which have been built up by wave action on the slopes of the boulder ridges of the district, at the 300-foot level, or higher, contain quantities of sand, mixed with larger gravel material. This could be screened to supply small amounts of sand for concrete, but could not be relied upon for a large tonnage. Unlike the river terrace sands, this material has not been subjected to much erosion, hence the grains are subangular to angular. A large percentage of the grains is composed of limestone.

A few scattered deposits of fluvio-glacial material are to be found in this district, but it is doubtful if they will furnish any considerable tonnage for concrete construction. Like the sands in the beach deposits, they are composed, for the most part, of limestone, but the grains are more rounded than in the beaches.

Typical samples of sand from this district were collected and tested for concrete. The results of these tests are given in the accompanying tables.

Gravels

The gravel supply of the district is chiefly obtained from raised sea beaches, which are mostly situated at the 300-foot level, or from 100 to 150 feet above the levels of the St. Lawrence river. As the land which stood above what is now the 300-foot level was confined to a group of small scattered islands, at the time of beach building, the amount of gravels formed was limited to small, isolated deposits.

Furthermore, these deposits, in addition to being small, are mostly situated beyond wagon haulage distance from the river, hence they cannot be relied upon as an important source of concrete material. They are worked, however, at various points to supply material for the maintenance of roads, and for building barn foundations.

Apparently, when the water fell below the 300-foot level, the sea was too shallow and the land too flat for effective wave work, consequently the gravels are either missing below that level or consist only of a layer generally not more than a foot in thickness, lying just below the surface soil. Notwithstanding the small amount of gravel in these thin sheets, they have been utilized at many points for road maintenance.

Many of the larger gravel deposits are limited in their usefulness, because intermingled with the finer materials they contained a high percentage of cobble stones and boulders which are too large to enter into the composition of a concrete mixture; hence the local users, in the absence of a stone crusher, are forced to reject considerable quantities of most of these deposits.

The source of gravel is still further curtailed by the fact that dwellings and farm buildings frequently occupy a position over the most desirable portions of the deposits.

It is probable, then, that for large quantities of concrete required for engineering works on the St. Lawrence, reliance will have to be placed on crushed stone derived from rock outcrops close to the river, such as those in the vicinity of Cardinal; the crushed stone being brought down in barges to the points where it is required. A large amount of field stone could also be assembled at most

localities along the river front, but for short land hauls of this kind of material some points are more favourable than others.

The following tables give the results of the tests on the sand samples collected:—

TABLE II

Summary Table of Tests of Sands from Localities in Eastern Canada

——	1907	1908	1912	1913	1917	1918	1921	1925	1928	1929	1930	1931
Per cent of gravel. Material retained on 3 mesh	Nil	Nil	Nil	11·86	Nil	Nil	Nil	24·83	Nil	5·18	14·67	Nil
Per cent sand. Material passing 3 mesh	100·08	100·0	100·0	88·14	100·0	100·0	100·0	75·17	100·0	94·82	85·33	100·0
Per cent silt in sand	2·90	3·15	8·20	2·37	5·45	4·30	5·35	5·35	3·35	2·45	3·85	5·40
Sp. Gr. sand	2·61	2·70	2·63	2·70	2·70	2·63	2·63	2·70	2·61	2·63	2·70	2·77
Weight per cubic foot sand	89·15	86·75	92·15	95·51	87·81	88·70	88·11	98·07	92·19	102·3	106·1	89·87
Per cent voids in sand	45·3	48·4	43·8	43·2	47·8	46·0	46·3	41·7	43·5	37·5	37·0	48·0
7 days	69	68	90	255	44	61	......	167	89	267	292	90
TENSILE STRENGTH OF SAND												
Average of three briquettes in pounds per square inch—												
Per cent Sample—Standard	41·05	40·5	53·6	151·8	26·2	36·3	......	99·4	53·0	158·9	173·8	53·6
28 days	118	120	150	352	77	133	......	288	166	394	413	187
Per cent Sample—Standard	39·6	40·3	50·3	118·1	25·8	44·6	......	96·7	55·7	132·2	138·6	62·7
7 days	668	530	902	2,196	307	657	......	1,570	774	2,396	2,938	764
COMPRESSION STRENGTH OF SAND												
Average of 3 cylinders (2″ diam. x 4″ high)—												
Per cent Sample—Standard	48·8	38·8	65·9	160·5	22·4	48·0	......	114·8	56·6	175·3	214·8	55·7
28 days	986	1,029	1,379	3,670	557	1,007	......	2,514	1,507	3,777	4,307	1,442
Pounds per square inch—												
Per cent Sample—Standard	43·7	45·5	61·1	162·5	24·8	44·6	......	111·3	66·7	167·2	190·8	63·8

TABLE II—*Continued*

Summary Table of Tests of Sands from Localities in Eastern Canada

——	1932	1933	2007	2008	2009	2012	2014	2015	2020	2021	2037	2038
Per cent of gravel. Material retained on 3 mesh	Nil	21·97	53·91	Nil	24·65	Nil	56·07	Nil	Nil	Nil	Nil	21·68
Per cent sand. Material passing 3 mesh	100·0	78·03	46·09	100·0	75·35	100·0	43·93	100·0	100·0	100·0	100·0	78·32
Per cent silt in sand	5·50	3·25	35·55	37·30	2·05	31·55	9·90	19·97	15·00	13·30	4·55	4·30
Sp. Gr. sand	2·77	2·70	2·43	2·50	2·55	2·50	2·43	2·50	2·43	2·55	2·55	2·50
Weight per cubic foot sand	92·15	101·2	98·35	92·75	101·4	97·12	104·0	90·36	92·36	89·24	92·11	93·75
Per cent voids in sand	46·7	39·9	35·1	40·6	36·3	37·8	31·5	42·1	39·1	43·9	42·1	39·1
7 days	123	282	164	92	170	105	222	42	95	49	108	191
TENSILE STRENGTH OF SAND												
Average of three briquettes in pounds per square inch—												
Per cent Sample—Standard	73·2	167·8	96·5	54·1	100·0	61·8	130·6	24·7	55·9	28·8	63·5	112·4
28 days	213	366	269	205	441	202	429	140	183	98	267	343
Per cent Sample—Standard	71·5	122·8	88·5	67·4	145·0	66·4	141·1	46·4	60·2	32·2	87·8	112·8
7 days	986	2,673	1,061	520	2,663	658	1,613	329	796	339	626	1,316
COMPRESSION STRENGTH OF SAND												
Average of 3 cylinders (2″ diam. x 4″ high)—												
Per cent Sample—Standard	72·1	195·4	79·4	38·9	199·2	49·2	120·6	24·6	59·5	25·4	46·8	98·4
28 days	1,814	3,893	2,960	1,305	5,443	1,454	3,573	1,039	2,005	817	1,655	3,386
Pounds per square inch—												
Per cent Sample—Standard	80·3	172·3	95·6	42·1	176·1	46·9	115·4	33·6	64·7	26·4	53·4	115·7

TABLE III

Granulometric Analysis of Sands from Localities in Eastern Ontario

	1907	1908	1912	1913	1917	1918	1925	1928	1929	1930	1931	1932
Cumulative per cent	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
Retained on 4 mesh	......	......	......	1·81	......	......	9·40	......	2·90	5·47	......	......
" 6 "	......	......	......	3·22	......	......	17·05	......	6·35	10·84	......	......
" 8 "	......	......	......	4·92	......	......	23·55	......	10·25	18·89	......	......
" 10 "	......	......	......	7·02	......	......	29·65	......	17·15	28·64	......	......
" 14 "	......	......	0·45	10·82	......	......	33·35	0·60	23·85	37·64	......	1·05
" 20 "	......	......	1·06	20·97	0·15	......	38·45	1·30	34·15	45·09	......	1·45
" 28 "	0·40	0·35	1·81	42·53	0·35	......	44·20	1·95	47·50	53·94	......	2·15
" 35 "	0·90	1·43	5·81	67·83	1·00	0·10	54·61	9·35	62·20	64·87	0·45	7·45
" 48 "	5·50	6·68	18·11	83·26	2·66	1·10	69·96	22·25	76·86	76·57	5·31	29·50
" 65 "	29·95	30·60	43·76	89·41	7·26	16·10	84·26	51·10	86·81	35·72	30·42	56·65
" 100 "	77·56	74·91	74·01	92·95	38·26	63·68	93·52	87·00	93·16	93·02	68·68	79·50
" 150 "	88·32	87·51	81·94	93·80	61·16	76·12	95·37	93·97	95·91	94·77	78·19	85·85
" 200 "	98·03	97·11	93·34	94·20	93·21	91·76	96·88	98·81	97·86	97·39	91·50	94·35
Average fineness	73·33	74·79	76·08	36·22	107·56	90·80	34·60	59·99	33·65	32·33	84·64	67·33
Type of deposit	a.	a.	a.	b.	a.	a.	b.	a.	c.	c.	c.	c.

TABLE III—*Continued*

Granulometric Analysis of Sands from Localities in Eastern Ontario

	1933	2007	2008	2009	2012	2014	1015	2920	2021	2037	2038
Cumulative per cent	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
Retained on 4 mesh	10·16	9·30	......	6·53	......	9·36	......	......	......	......	1·31
" 6 "	18·67	16·23	......	19·48	......	18·66	......	......	......	......	2·86
" 8 "	26·53	22·03	......	36·03	......	25·56	......	......	0·28	0·28	5·27
" 10 "	36·04	27·38	......	67·84	......	31·66	......	1·10	0·64	0·54	11·94
" 14 "	44·05	30·78	......	83·70	0·12	34·81	0·05	2·18	1·09	0·84	20·75
" 20 "	53·20	35·05	0·10	93·96	0·23	38·33	0·55	5·83	1·94	1·31	38·65
" 28 "	62·81	43·70	0·40	97·11	0·48	42·19	2·40	16·34	10·37	1·56	64·65
" 35 "	77·41	61·44	1·15	98·61	4·41	46·99	6·20	48·71	21·27	17·88	81·78
" 48 "	88·36	84·09	5·25	99·07	26·39	66·20	26·30	79·06	67·02	52·25	91·64
" 65 "	93·06	90·09	21·40	99·17	54·48	85·45	58·06	87·56	85·82	77·55	73·51
" 100 "	95·06	92·99	65·25	99·22	79·94	94·55	87·21	92·61	96·97	93·30	94·66
" 150 "	95·51	93·74	79·95	99·23	86·84	96·74	92·18	94·24	98·64	95·65	95·96
" 200 "	96·31	96·18	97·55	99·24	97·39	98·04	96·68	97·04	99·69	98·43	96·71
Average fineness	25·91	33·07	84·83	9·41	66·17	33·60	60·33	40·69	40·64	48·28	27·58
Type of deposit	b.	......	......	......	......	......	......	......	......	......	......

LIST OF SAMPLE LOCALITIES

Description of Sand Samples

Sample No. 1907.—Locality: south half lot 37, concession I, township Osnabruck, Stormont county.

This sample was taken from drillings with post hole auger, through 6 feet of sand, from top to bottom of dune.

Sample No. 1908.—Locality: lot 7, concession I, township of Williamsburg, Dundas county.

Taken from drillings from post hole auger, from top to bottom of dune, 8 feet in depth.

Sample No. 1913.—Locality: lot 23, concession VIII, township of Cornwall, Stormont county.

A prominent boulder ridge running N.E. and S.W. is flanked on the N.W. by a steep pitching beach ridge. A pit has been opened up on this beach, and a small amount of gravel was obtained. To the southwestern part of the pit, about 4 feet of sand has been exposed, nicely stratified, and covered by about 2½ feet of gravelly till. The bottom of the sand was not exposed, nor was its continuation to the southwest determined, as it was covered. The sample was taken vertically down the face of the exposed layers.

Sample No. 1917.—Locality: lot 22, concession I, township of Williamsburg, Dundas county.

Sample taken from borings from auger drill in dunes to southwest corner of cemetery. The sand was of uniform texture throughout the whole 8 feet drilled.

Sample No. 1918.—Locality: lot 15, concession I, township of Osnabruck, Stormont county.

Sample taken from bank of St. Lawrence river from 12-foot section of sand overlying clay. The top 3 feet of the sand was iron stained, and reddish in colour, below which, for 7 feet, a clean, greyish sand was obtained. The bottom 2 feet was slightly clayey.

Sample No. 1925.—Locality: lot 23, concession I, N.S.R. township Charlottenburg, Glengarry county.

Sand and gravel pit owned by Frank Lefevre. This is a well developed beach ridge, built upon the western end of a boulder ridge. Stratification is well marked wherever a face is exposed, and shells are abundant throughout. The sample was taken from a loaded rig, which was drawing material for concrete from this pit.

Sample No. 1928.—Locality: lot 6, concession I, township of Osnabruck, Stormont county.

Sample taken from sand pit opened on east side of road opposite cemetery. The sand contains numerous shells.

Samples Nos. 1929-1930-1931-1932.—Locality: north half lot 5, concession IV, N.S.R., township of Charlottenburg, Glengarry county.

This deposit is probably of glacio-fluviatile origin, and is composed of sand and gravel, covered in places with a thin layer, 12 inches thick, of beach material carrying shell. No shells were to be found in the material sampled. Four samples were taken from different parts of this pit to represent four different grades of material. No. 1929—fine gravel with sand; No. 1930—coarse gravel with sand; No. 1931—fine sand; No. 1932—coarse sand.

Sample No. 1933.—Locality: lot 6, concession VIII, township of Charlottenburg, Glengarry county.

There is a pit opened on this property on a ridge of considerable extent. It rises fully 40 feet above the valley. Shells are abundant, and there are considerable quantities of coarse material. General sample taken.

Sample No. 2007.—Locality: ½ mile southeast of Northfield station of the New York Central railway.

Sample No. 2008.—Locality: north ½ lot 35, con. IV, township of Edwardsburg, Grenville county. Average sample of sand taken from 12-foot section.

Sample No. 2009.—Locality: lot 3, con. VI, township of Augusta, Grenville county.

Sample No. 2012.—Locality: lot 3, con. I, township of Augusta, Grenville county. Sand dune just north of cemetery at Prescott. Average of 10 feet in depth.

Sample No. 2014.—Locality: sample of concrete material from the Windfall pit taken from a face of 8 feet at the southern end of the pit.

Sample No. 2015.—Locality: lot 24, con. IV, township of Matilda, Dundas county. Sample from sand dune on north side of road. Average of material from a 9-foot auger hole.

Sample No. 2020.—Locality: sample of recent river sand from the east bank at the mouth of Chateauguay river.

Sample No. 2021.—Locality: sample of river sand from off the north shore of St. Bernard's island. Sample taken from under water.

Sample No. 2037.—Locality: sample of fluvio-glacial sand from pit on the south side of the railway ¼ mile west of River Baudet station, Quebec.

Sample No. 2038.—Locality: sample of gravelly sand from morainic ridge 2 miles northwest of River Baudet station, Que.

EXPLANATION OF PHYSICAL TESTS ON SANDS

The samples of sand tested averaged about 20 pounds in weight. They were passed through a 3-mesh screen, and the material retained on the screen was called gravel, and that passing through was called sand. The results of the tests tabulated in the accompanying tables were obtained from the material passing through the 3-mesh screen.

Granulometric Analysis

In all cases, 100 grams of the sand to be tested was employed. The results obtained from this test give an idea of the texture of the sand with regard to size of grain. The test was carried out as follows:—

The 100-gram sample was placed on the coarsest screen, which was nested on the next size finer, and so on down to the 200-mesh, with retaining pan on the bottom. The nest of screens was then thoroughly shaken on a mechanical shaker for 10 minutes, the material retained on each screen being collected, weighed, and noted. The sample, in the first place, being 100 grams, the weight recorded as retained on each screen is the percentage retained on that screen and passing through the next size larger; and the cumulative percentage, or the percentage of all material that would be retained on any one screen, if that screen alone were employed, can readily be determined by totalling the weights retained on all coarser screens.

The results obtained in these tests are tabulated as cumulative percentages in the accompanying table.

To gain an idea of the fineness of the grain of the sand, and to be able to express this in one figure for purposes of comparison, the average fineness of

each sample was calculated as follows: The quantity of material passing through each screen and retained on the next smaller was multiplied by the mesh of the screen passed through and the results thus obtained totalled, and divided by 100, the final results being the average fineness. In other words, if all the grains of the sample were brought to an average size, they would just pass through a screen whose mesh was equal to the average fineness of the sample.

Percentage of Silt and Clay

The percentage of silt and clay was determined by the elutriation method, 100 grams of sand being used in each case. The weighed sample of sand was placed in a glass vessel and subjected to a rising current of water of constant head which carried away the silt and clay. When the water being siphoned off was clear, the material remaining in the vessel was dried to constant weight and weighed, and the percentage of silt and clay calculated.

Specific Gravity

The specific gravity was determined by means of a Le Chatelier specific gravity flask. The bulk of the flask was filled with water, and the height of the column of water read on the graduated stem. Fifty grams of sand were admitted, care being taken to permit the escape of the air; and the new height of the water column read. The difference in the two readings gave the volume of water displaced by 50 grams of sand. From this data the specific gravity of the sand was computed.

Weight per Cubic Foot and Percentage of Voids

The weight per cubic foot, and the percentage of voids, were calculated from the weight of 500 c.c. of sand. The method of obtaining the weight of 500 c.c. of sand was as follows: Two brass cylinders were used, one having a volume of exactly 500 c.c. and the other having an outside diameter slightly smaller than the inside diameter of the first one, but twice as long. The longer cylinder was filled with sand, and the 500 c.c. cylinder inverted over the top of it. The two cylinders were then inverted and the long cylinder withdrawn, leaving the sand in the graduated cylinder. The sand was then struck off level, and the amount of sand in the 500 c.c. cylinder weighed. The weight per cubic foot when calculated is probably lower than when other methods are employed for compacting the sand in the 500 c.c. cylinders; but it was found that the results obtained on the same sand, when this method was used, were so uniform, even when different operators performed the test, that it was thought advisable to adopt it.

The percentage of voids calculated from the weight obtained by the above method is also, for the same reason, higher than when other methods are employed.

Tensile Strength

The tensile test was made in the usual manner on briquettes similar to those used in standard cement testing, using a 1:3 mixture. Three briquettes were broken at 7 days and three at 28 days, and compared with briquettes made of the same cement and standard Ottawa, Ills., sand.

Compressive Strength

The compressive tests were made on mixes of 1:3 mortar, using the same cement with the different sands to be tested. Cylinders 2 inches by 4 inches were employed, and breaks were made at 7 and 28 days, and compared with standard cylinders, run concurrently.

An examination of the tabulated results of all these tests shows that the finer sands make poor concrete material. As a general rule, if there is no organic matter present, and the percentage of silt and clay is low, a sand which has 75 per cent retained on the 48 mesh will make a good concrete, one that would be safe to employ, with a coarse aggregate, for concrete work. A good sand should have a strength at least equal to the standard, at both 7 and 28 days.

DESCRIPTION OF GRAVEL DEPOSITS

GRENVILLE COUNTY, ONT.

Augusta Township.—Only a narrow strip of the eastern part of Augusta is included in the Morrisburg sheet. It contains two gravel deposits of importance, the larger lying just east of the village of Roebuck, in lot 4, concession VI. This deposit covers about 70 acres and has a thickness of at least 14 feet in one of the excavations made in removing the gravel. The material is largely composed of beds of pea-size gravel and sand associated with coarser gravel, with occasional cobble stones scattered through the mass.

There is a smaller deposit of gravel covering about 20 acres, on lot 3, concession VIII.

A fuller account of the gravel deposits in Augusta township and their commercial development is given in the Geological Survey report for 1915.[1]

A sample of sand taken from the gravel pit at Roebuck, owned by Mrs. Smith, was tested in order to determine its fitness for concrete construction, the results being given elsewhere in the report. (Sample No. 2009).

Edwardsburg Township.—Deposits of gravel are scattered rather sparingly over the western part of Edwardsburg, and there are none in the southern part adjacent to the St. Lawrence river, the nearest deposit to the river being at the Froom gravel pit one mile north of the village of Cardinal.

In this deposit which extends across lots 4 and 5, con. I, there is a face of 7 feet opened up and the material shows a slight stratification. The gravel is fairly well graded for coarse concrete and is comparatively clean. It ranges in size from 6-inch material down to fine sand. It is a typical marine beach deposit built on the northwest slope of a boulder till ridge and carries a few well developed specimens of shells. (See Appendix).

One of the largest deposits in the township is on lot 12, con. VII, about a mile southeast of the village of Ventnor (Plate XXI).

It covers an area of at least 20 acres and is 15 feet in thickness. The material is mostly fine, clean gravel of fluvio-glacial origin, overlain by 3 feet of boulders embedded in sandy clay. There are two excavations in this deposit, from which gravel is drawn for road surfacing; and on account of its freedom from silt and clay it is also extensively sold for concrete mixtures. The scarcity

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[1] Road Material Surveys in 1915, Memoir 99, Geological Survey, Ottawa.

of gravels suitable for concrete construction in this region is evident from the fact that farmers come from a distance of 15 miles to this deposit, for gravel.

Another important gravel deposit is situated about two miles south of Spencerville. A great part of this deposit was used during the years 1919 and 1920 in the construction of the Ottawa-Prescott highway. The material is mostly coarse gravel with a considerable percentage of cobble stones. As can be seen from the map, bed-rock was encountered beneath the gravel. The deposit is owned by Dr. McIntosh, of Spencerville. On the south half of lot 25, con IX, a small but well developed, stratified gravel deposit has recently been opened up. A face of 12 feet is exposed in this pit, and the material varies from cobble stones 1 foot in diameter to fine sand. The floor of the pit is flat lying limestone or dolomite.

On lot 12, con. III, a small gravel and sand pit has been opened on the north side of the road. This deposit is a beach ridge, built on the southwestern end of a boulder clay elevation. The material in the east end of the pit is gravel and cobble stones up to 6 inches in diameter, but gradually becomes finer to the southwest. A large reserve supply of gravel for local use still remains in this deposit.

The smaller gravel deposits in Edwardsburg are described in detail in the two reports on road materials by Messrs. Reinecke and Picher.

DUNDAS COUNTY, ONT.

Matilda Township.—Deposits of gravel are extremely rare in Matilda and there are none near the banks of the St. Lawrence river. The few deposits that exist are small in extent and shallow, and are principally used for the surfacing of roads nearby, or for local concrete work. This township, as well as Williamsburg, is situated in the comparatively flat area between two glacial morainal belts, and as gravel deposits are generally connected with moraine features there is not much probability of finding any deposits other than those already known. On lots 21 and 22, con. II, there is a well marked gravel ridge covered with a varying amount of fine dune sand. The sand shows distinct stratification in places. On the stratified sand, which is light coloured, rests, apparently unconformably, an unstratified reddish sand of about the same texture. In places the stratified sand is missing and the reddish sand rests directly on the marine gravels with a distinct line of demarkation. The gravel ridge is a true marine beach carrying considerable quantities of marine shells in the lower 5 feet of the face. The gravelly material varies from coarse sand up to cobble stones 10 inches in diameter. It is well and uniformly graded and is cleaner than the usual run of beach material. An analysis of the coarser pieces gave:—

Limestone	72%
Sandstone	4%
Archæan	24%

The percentage of Archæan material is higher than is usual in this kind of deposit. The deposit has had considerable material taken from it, but a small tonnage is still available.

Lots 11 and 12, Con. VI.

Williamsburg Township.—A gravel ridge about three-fourths of a mile in length and about 300 feet wide occurs on lots 11 and 12, con. VI. It is the property of Mr. Luther Deeks and has been used freely for road material, but

only a comparatively small portion of the gravels in the entire ridge has been excavated. The pits show a face of about 7 feet, composed of successive layers of gravel sloping to the southwest. The average size of the material is about three-quarters of an inch in diameter in the upper part of the ridge; but cobble stones are numerous in the lower part.

This is an unusually well formed beach ridge with three bars extending to the west. It rises about 20 feet above the surrounding country. The elevation at the base of the ridge is 289 feet, so that the crest of the ridge is about 309 feet above sea level. The low ground to the west of the ridge is swampy and bush covered. The slope and plain to the westward is cultivated. Shallow pits dug in a field on the lowest slope of the ridge revealed a mass of marine fossil shells in sand and gravel, underlying mud. The shells were all of one variety, *Saxicava rugosa.*

Lots 19 and 20, Con. VII.

A low narrow ridge parallels the road 2 miles east of Elma and extends for about a mile in a northerly direction beyond the limit of the Morrisburg sheet. This ridge contains patches of gravel from 2 to 5 feet in thickness and of small extent. The gravels are finer than in most of the other pits and carry a smaller percentage of cobble stones and boulders. The gravels at the southern end of this ridge are nearly all worked out.

Lot 5, Con. VI.

There is an extensive deposit of gravel at the southern end of a low bouldery ridge on lot 5, con. VI. It contains layers of pea gravel and a few thin streaks of sand; but most of the material is coarser limestone pebbles averaging about the size of potatoes. The deposit has been worked down to the underlying boulder clay, in places to a depth of 15 feet from the surface of the gravels.

This beach slopes toward the south and is backed by boulder clay which rises to the surface north of the gravels.

A great profusion of the fossil shells *Macoma* and *Saxicava,* principally in a fragmentary condition, are mixed with the gravels in places. This deposit still contains several years supply for local use.

The ridge in which these gravels are situated continues in a northerly direction into concession VII and follows the 300-foot contour running parallel to the road for about a mile on lot 2, to the north of the Morrisburg sheet.

There are gravels on the northern portion of this narrow ridge, but in shallow deposits from 2 to 5 feet at most.

A long, narrow, sinuous ridge of slight relief trends in a southwesterly direction from Bouckhill toward the boundary line between the townships of Williamsburg and Matilda, its total length being 5 miles and its width from 200 to 600 feet. Most of the surface of the ridge is strewn with large boulders, consisting mainly of crystalline Archæan rocks but including a few of Potsdam sandstone. Parts of the ridge are cultivated and the boulders piled along the fences, but most of it is woodland. At a few points sand or gravel accumulations have been laid down against the ridge by wave action but the deposits are not of large extent.

The largest gravel patch occurs on the western flank of the ridge, on the property of Mr. Omer Coughlin, on lot 35, on the line between the third and

fourth concessions. About 12 feet of gravel, overlying boulder clay, is exposed in a pit near the road where gravel for the roads is excavated. The deposit contains many cobblestones, most of them too large for road surfacing. The sand and fine gravel filling the spaces between the larger stones is the material most in use.

Fossil shells, *Macoma balthica*, are scattered plentifully through the deposit from top to bottom, and gravel of finer texture than the general body is found on the southwesterly slope of the beach. The beach curves in a northeasterly direction along the flank of the boulder ridge in concession III, and is probably over half a mile in length, but the total gravel content is not very large.

An analysis of the pebbles from the excavation in this deposit shows that 11 per cent are Archæan, 2 per cent sandstone, and 87 per cent limestone.

A narrow strip of beach gravels about a quarter of a mile in length occurs on the western flank of the long ridge near its northern extremity at Bouckhill. A cemetery occupies the southern tip of the gravel strip and the remainder of the area is cultivated. No excavation for gravel was seen on this deposit.

Between Bouckhill and the Coughlin pit the only gravels seen on the ridge occur on lot 28, where it is crossed by the road between the fourth and fifth concessions.

The ridge at this point consists of a thin deposit of yellowish sand and fine gravel which is used to some extent for road surfacing.

Lot 31, Cons. V and VI.

A pit has been opened up at this locality on a beach gravel deposit built on the southwest slope of a boulder clay elevation. A considerable amount of material has been taken from this deposit, and at present there is a face of 10 feet exposed. Cobble stones up to 6 inches in diameter, mostly limestone, are common and a layer of fine gravel and sand, 18 inches thick, containing shells resting on boulder clay, is exposed at the bottom of the face. Above this stratum and apparently resting unconformably on it is a coarse bouldery gravel with alternate coarse and fine seams through it, and about 6 inches of bouldery till lies on top of the whole deposit. The coarse upper gravel contains only fragments of shells very sparsely scattered through it. There is still considerable tonnage available for local use.

STORMONT COUNTY, ONT.

Osnabruck Township.—Gravel deposits are more numerous and larger in this township than in the township of Williamsburg, but none of them are extensive. They supply material for the surfacing of roads, and in a few of the deposits a small supply of clean gravel can be obtained for use in concrete building. But they can only be relied upon to supply the local needs of the township.

Most of the deposits contain so many large stones that the actual amount of gravel obtained represents a comparatively small portion of the mass.

The largest deposits in Osnabruck are remote from the St. Lawrence River front.

The following descriptions apply to the more important gravel pits that are worked for road material or concrete. Several others which are small or nearly worked out are not described but are shown on the map.

A very finely formed beach ridge, facing southerly, crosses the road between lots 30 and 31 in the sixth concession, on the property of Mr. J. W. Hamilton.

Two pits have been opened on this deposit behind Mr. Hamilton's house, to the west of the road, to supply gravel for concrete construction and road surfacing. The gravel is stratified and well graded from fine clean pea gravel to 4-inch material, about 90 per cent being limestone. The deposit varies from 5 to 10 feet in depth overlying boulder clay. There is a larger percentage of fine gravel in these pits than is usually the case in this district. The extent of the deposit is not known, but the beach ridge appears to follow the 300-foot contour line for a considerable distance east of the road. As far as could be seen no test pits had been opened along the slopes of the ridge in that direction.

The pit owned and worked by Mr. N. Gallinger lies just beside the road, on lot 31 in the fourth concession. A large excavation has been made here and the gravel exposed in the highest portion of the pit shows a thickness of 20 feet. There is quite a variation in the size of the material.

Near the bottom of the pit there is a three-foot bed of fine gravel, sand, and shell fragments, the latter being almost as abundant as the pebbles. A great part of the material in the face is cobble stones, mostly partly rounded limestone with some well rounded harder stones, an average analysis of the composition of the gravel being:—

Archæan pebbles	7%
Sandstone "	10%
Limestone "	83%

A considerable part of the output of this pit is used in concrete construction and the gravel is frequently hauled as far as Aultsville.

The best part of the gravel remaining in this deposit lies under the buildings and orchard adjacent to the pit.

A gravel pit, owned by Mr. Wm. N. Hollister, on lot 26 in the fourth concession, is opened on the southwest point of a boulder strewn ridge which trends northeast for about a mile. It is freely drawn upon to supply road and concrete materials, and a working face 700 feet long and 17 feet high was exposed in 1919. The deposit is made up of large stones irregularly laid down, with fine clean gravel filling the spaces between them (see Plate XXII).

The stones in the upper five feet average about a foot in diameter; below, the material is somewhat finer, the average being 4 to 6-inch stones cemented together with pea gravel; and in the bottom of the pit there are a few feet of roughly stratified pea-sized gravel. Most of the stones in the deposit are rather angular and average from 10 to 12 inches in diameter. Several large blocks of limestone, 3 to 5 feet long, are embedded in the upper 5 feet of the deposit, and Archæan boulders 3 feet in diameter are common. Nearly 90 per cent of the smaller stones are limestone.

Marine fossil shells, *Saxicava rugosa* and *Macoma balthica*, are extremely abundant throughout this deposit, from the surface to the bottom. They are found with the valves together, in single shells and in fragments, lying under the heaviest boulders in the heap. Very fragile fossil shells of *Balarius crenatus* may be seen still sticking to the boulders on which they lived when the sea water washed this beach.

About a quarter of a mile northeast of the Hollister pit and backed by the same bouldery ridge, there is a smaller patch of gravels in which a pit about 250 feet across and 6 to 8 feet deep has been excavated to supply road material.

The finest material was found nearest to the surface, but a good deal of the lower part of the deposit was discarded as being too coarse for road surfacing and now lies in heaps on the bottom of the worked out portions of the pits.

The entire ridge against which these gravel deposits have been built by wave action appears to be made up of a network of boulders with only a small proportion of fine materials. A crusher installed at this point would have a steady supply of stone for a long period, from the discarded materials in the two pits and the stone from the entire ridge.

A shallow deposit of gravel occurs on the road between the third and fourth concession on the boundary line between the townships of Osnabruck and Williamsburg.

This deposit contains a number of large blocks of limestone as well as the usual quantity of Archæan and sandstone boulders. It also contains about 2 to 4 feet of stratified gravel suitable for road surfacing. The deposit is owned by Mr. P. Murphy.

Cornwall Township.—Gravel deposits in this township and Charlottenburg are more numerous and of greater extent than in any other townships in the district. These two townships contain the southern limits of an extensive morainic belt and the marine waters have had an abundance of material upon which to work. In consequence, deposits of gravelly material may be found on the westerly slopes of nearly every boulder ridge, the character of the deposit depending upon whether or not the sea has had an opportunity to build a beach. Many of these deposits have been opened up and small quantities of material obtained for road surfacing or local concrete work. Two of the largest deposits in the district are to be found in this township, namely, the Northfield pit and the Windfall pit. Descriptions of these two deposits and of a few other representative ones follow.

Northfield Gravel Deposits

One of the largest accumulations of gravel in the district occurs about half a mile east of Northfield station on the New York Central railway. (See sketch Fig. 3.) On the eastern end of this ridge the railway has a siding, and a large amount of material has been excavated by steam shovel. A face of from 10 to 12 feet is exposed for a distance of some 400 yards. The material in this face ranges from 6 inches to coarse sand and none of it is very clean. It has been used mostly for railway ballast. On the north side of this deposit another pit has been opened up, which shows a face about 12 feet high. Although cobble stones are numerous in this pit, there is a large amount of medium sized gravel. The deposit is made up of alternating layers of cobble stones and gravel. When visited in the summer of 1920, material was being hauled to the railway at Northfield station for shipment to Russell, Ont., for concrete work. A general sample was taken of the finer material from this pit and tested as sample No. 2007.

Windfall Deposit

A pit has been opened on this deposit which appears to be one of the largest accumulations of marine beach gravels in the region. The gravels lie

on the westerly face of a boulder ridge which extends in a north-south direction for about a mile. They have been traced by tests pits for about half the length of the ridge. The excavation opened for gravels was about 300 feet long and 100 feet wide, with a maximum thickness of 14 feet (Plate XIX).

The deposit consists of a mass of roughly stratified sand, gravel, cobble stones, and fossil shells, with a layer about 18 inches thick of large angular boulders on top of the gravel. A general sample from this deposit was taken and tested for suitability for concrete. (Sample No. 2014).

Fig. 3. Sketch plan of Northfield gravel pit. Scale: 500 feet to 1 inch.

A well developed gravel beach resting on the western slope of a boulder ridge can be seen on the east road about 1¼ mile north of the town of Cornwall. The ridge has been opened up for gravel and some good material taken out. A face of 7 feet is exposed on the north side of the road, and clayey material has been encountered in the bottom of the pit. The upper 4 feet of the face is entirely devoid of shells, while the lower 3 feet show shells (*Saxicava* and *Macoma*) in great abundance. There is a very marked dividing line between shell-less beds and shelly beds. The upper 4 feet carries more cobble stones than

the lower part. Material from this pit is being used for concrete work in Cornwall, and there is sufficient for local use for several years to come. Fallon Bros. are the owners.

A well formed beach is to be seen on the western side of a boulder ridge on the west side of the King's road at the crossing of the New York Central railway about 2½ miles northeast of Moulinette. It bears 200 degrees magnetic, and has a definite slope of 15 degrees. The foot of the deposit tails off into a swamp. There is very little material over 6-inch size, and most of it is 2 inches and under. It is over one-fourth of a mile long and only a small quantity has so far been excavated. Shells are abundant and the material is well graded and clean.

One mile west of Black River station on the New York Central railway, there is a deposit of beach gravels on the northwest side of a stony ridge. It is composed mostly of cobble stones about 5-inch diameter. The spaces between the stones are filled with clean sand, gravel, and fossil marine shells. This pit has been worked for a long time for road materials and a large pile of stones which could not be used for road surfacing has accumulated in worked out portions of the excavation. A face of about 9 or 10 feet is obtained but it is probable that not more than half of the contents of the deposit is utilized. This beach is built on the flanks of an extensive ridge, and it is probable that the gravels extend much farther both ways from the point opened for road material; but, as in most other cases of this kind, prospecting by means of test pits would be necessary to prove the extension of the gravels. (Plate X).

Half a mile northeast of Moulinette there is a small pit on the property of Thos. Clary, in a small beach remnant showing sand and gravel with marine shells. The material is sold in Cornwall for building purposes. Directly to the north of this pit there is a boulder ridge, on the western slope of which a gravel beach is indicated by woodchuck holes showing sand, gravel and shells, but it has not been opened up.

About 2 miles northeast of Harrison, Ont., there is a small gravel pit on a steep slope facing the north. The deposit is unusual because it has a bed of clean coarse sand a few feet thick between coarse gravel and cobble stones. The deposit faces north and lies, as usual, against a boulder ridge which is very stony on the surface. It is a marine beach deposit, for it contains numerous pockets of the fossil shells, *Macoma* and *Saxicava*. (Sample No. 1913).

About 1 mile southeast of Bonville, Ont., there is a small pit owned by Mr. MacDonald from which considerable material has been taken. The material is composed of fairly clean gravels, with a face of about 9 feet, and is overlain by sand on the west slope.

GLENGARRY COUNTY, ONT.

Charlottenburg Township.—The topography of this township is similar to that of Cornwall township lying immediately to the west, and there are numerous deposits of gravel scattered through the part of the township lying back from the St. Lawrence river front. Adjacent to the river, gravel deposits are scarce, and where present are only of small extent. Several deposits of fluvio-glacial origin have been opened up in this township, and it is possible that there are others of a similar nature buried beneath the drift material.

All the deposits noted are indicated on the maps and the more important are briefly described below.

Half a mile west of Glen Gordon station on the Canadian Pacific railway, a pit has been opened on the north side of the road, on property owned by Mr. W. Mitchell. The only surface indication of this deposit is a low ridge or swell in the otherwise flat land. The face of the excavation opened to supply road material and concrete aggregate shows an irregular accumulation of gravel, sand, and silt, often arranged in lens-like forms. An accumulation of heavy blocks of rock and boulders occupies the highest part of the ridge. The deposit is so irregular in character that the material required has to be selected from different parts of the face. There is consequently a good deal of dead work to do, and considerable waste material to be disposed of, such as silt, very fine sand, and large boulders and blocks of rock.

It is impossible to say how far the gravels extend under the surface of the ground in the vicinity, as this is one of the buried deposits of fluvio-glacial material, the presence of which is only feebly indicated on the surface or not at all. It is quite probable that other deposits of a similar nature could be located in this neighbourhood by means of test pits. This gravel pit supplies a quantity of very clean gravel suitable for concrete work as well as road material. A large quantity of boulders and discarded blocks of rock is piled up on the bottom of the excavation. These consist of limestone, sandstone, and granitic rocks, some of the latter being in an advanced state of decomposition. A further supply of road material could be obtained by crushing the boulders.

On the north half of lot 5, con. IV of this township, a pit has been opened on the property of Chas. Proctor. This deposit is of fluvio-glacial origin and furnishes a great variety of different grades of sands and gravels. The coarser grades are excellent for concrete use while the finer sands are suitable for use in mortar. There is an overburden of from 1 to 3 feet of badly sorted beach material carrying marine shells. No idea was obtained as to the depth to which the sands and gravels extend. Four samples were taken from this pit to represent the different grades of material which could be obtained. See samples Nos. 1929, 1930, 1931 and 1932.

In lot 6, con. VIII, on the property of Parfait Beaupré, a deposit of beach gravels and sand has been opened up. The material consists of bedded sands and fine grey gravels for a thickness of 5 feet or more, overlain by 3 feet of fragments of rock of cobble stone size and pebbles. A layer of marine fossil shells, embedded in silty sand a few inches thick, occurs between the fine and coarse material. (See Plate XXV).

The bottom of the excavation is at the lowest drainage level of the district and, although gravel is still to be found in the bottom of the pit in places, it would be difficult to recover it on account of water. The lower gravels are also to be found in the form of bars extending over a considerable part of the depression in the vicinity of the excavation at the base of the hill, from which gravels are being drawn at the present time. Sample No. 1933 was taken from this deposit.

A pit has been opened up on the property of Joseph Riley on lot 20, con. VI, and two pits on the same ridge to the west of this property. The material consists of a dirty gravel ranging from pea size up to four inches. The pebbles are not well rounded, but a considerable quantity has been used for road work.

A gravel pit has been excavated by Frank Lefevre on lot 23, con. I, N.S.R. This is a well developed beach ridge, built up on the western end of a boulder ridge. Stratification is well developed wherever a face is exposed, and shells are

abundant throughout. A sample of the gravel from this pit was taken from a loaded rig which was drawing material for concrete. Sample No. 1925. A gravel bar seems to extend down the valley from the deposit.

About half way between Williamstown and Macgillivray Bridge, on the south side of Raisin river, there is a gravel pit 10 feet in depth at its deepest point and it is probable that gravels are to be found in the field at the east side of the road east of the present pit.

Half a mile north of the Canadian Pacific railway line from Montreal to Toronto, and 3 miles east of St. Clet station, there is an abandoned gravel pit with a siding from the railway. A large amount of material has been removed from this deposit for use as railway ballast. The deposit is a sand bar and is part of the St. Lazare sand plateau noted elsewhere. The southern point of the bar comes almost to the railway, rising about 3 feet above the plain to the south. The slope rises rapidly northward and attains a height of about 20 feet half a mile from the railway. The deposit has been worked in a large circular excavation having an area of about one square mile. Judging from an examination of the banks at the edge of the excavation the deposit consisted mostly of sand; with an occasional pebble and, at a few places, small layers of gravel a few inches thick.

A large sand and gravel deposit outcrops at intervals over a distance of nearly four miles, commencing on the bank of the St. Lawrence river on the west side of the mouth of Baudet river at McKie point and extending in a northerly and westerly direction with only a few breaks to a point about 2½ miles north of Baudet station on the Grand Trunk railway.

The surface of this ridge from the river road to McKie point is strewn with large boulders and angular blocks, and there is also a fair proportion of rounded cobblestones and pebbles exposed. The southern part of the moraine is flatter and wider than the northern part and contains finer materials. Sands and concrete gravels abound in the southern portion, but they are very unequally distributed and occur mostly in patches surrounded by silt or clay.

To the north of the river road a considerable amount of material has been excavated from this moraine, and a pit is being worked at the present time on the deposit immediately south of the railway, from which good concrete material is obtained. Sample No. 2038 was taken from this pit, which is owned and operated by Mr. Ed. Bourbonnais, of Baudet, Que.

The ridge has not been opened to any extent north of the railway, and it disappears on the north side of the Baudet river or else is buried, but rises again about a mile north of the river, where the deposit contains a good deal of sand and a fair proportion of cobble stones mixed with gravel. The sand occurs mostly as a coarse yellowish layer above the gravels, the whole extending downwards for a distance of 10 or 12 feet from the surface.

A plant for the manufacture of concrete blocks and culverts is situated close to this part of the deposit. Culverts up to 30 inches inside diameter are made.

The low ridge can be traced farther to the north. Test holes and gravel pits show that the sand and gravel is continuous for from one-half to three-quarters of a mile farther north. Its width at the north is about one-eighth of a mile. The last outcrop of sand and gravel was seen on the property of Mr. I. B. Martin, or about 2½ miles north of the village of Baudet. The greater part of the deposit on Martin's property consists of sand but there is also a quantity of fine gravel present.

It cannot be stated definitely that this deposit is continuous from the St. Lawrence river, but there is enough evidence in the pits already opened to show that it is one of the largest deposits in the region and one of the few in which a steam shovel could be put to work.

VAUDREUIL, BEAUHARNOIS AND CHATEAUGUAY COUNTIES, QUE.

In these three counties, as shown on the map, there are practically no gravel pits, the greatest part of the area being flat lying, marine clays. Probably small quantities of recent river sands could be obtained from the river for local use, by means of dredging.

CONCLUSIONS

Sand Deposits

There are four sources of sand in the area examined, namely (1) Recent river sands; (2) River terrace and dune sands; (3) Beach deposit sands; (4) Fluvio-glacial sands.

(1) Recent river sands. The sands obtained from recent river deposits are very fine in texture, clean and comparatively well rounded. They are mostly too fine for use in concrete but would be suitable for brick mortar.

(2) River terrace and dune sands. These are mostly very fine in texture and contain appreciable quantities of silt and clay. They are totally unsuited for use in large concrete work.

(3) Beach deposit sands. There are numerous beach deposits built by wave action on the slopes of some of the morainic ridges which occur in the region. They are generally small in extent and could not be depended on to furnish, except in a few cases, any considerable quantities for concrete. The beaches generally contain a large proportion of coarse material and the texture varies in different parts of the same beach. As a rule sand from a deposit of this nature makes a good concrete mixture. Good examples of this class of deposit are samples Nos. 1913 and 1925.

(4) Fluvio-glacial sand. Fluvio-glacial deposits of sand and gravel are found in a few places in the district. The coarser material in these deposits makes a good grade of concrete and the finer sand would also be suitable for concrete when mixed with a coarser aggregate. With the exception of that at Baudet, the deposits of this class so far found are of small extent and cannot be counted on for a large tonnage.

Gravel Deposits

There are no known gravel deposits near the St. Lawrence river in the area examined, the nearest being about two miles from the river bank.

Most of the deposits are small in extent and of irregular composition as regards texture. Only three deposits in the entire area are considered to be of sufficient extent to be worked by steam shovel. These large deposits are situated: one near Northfield on the Ottawa and New York railway, 12 miles north of Cornwall, Ontario; another, known as the Windfall gravel pit, four miles south of the Northfield gravel pit and two miles from the nearest railway; and the third in Soulanges county, Quebec, near the village of Baudet.

The line of the Grand Trunk railway passing through the area examined, was newly ballasted during the years 1919 and 1920, with gravel from an

extensive ridge of fluvio-glacial origin situated one mile south of the town of Renfrew. The hauling distance by rail for this gravel averaged about 100 miles. The engineers of the Grand Trunk railway apparently did not consider that any of the nearby supplies of gravel were adequate for their purpose.

CONCRETE MATERIALS

The materials used in concrete construction are cement, sand, and gravel or broken stone.[1] The cement in most cases is bought by specification, and frequent tests are run to make sure that the material delivered is up to the standard. The sand and gravel or broken stone is seldom tested, although generally, these materials compose more than 80 per cent of the total mass, and, in many instances, where concrete has failed, it has been proved that the cause of failure was due to the poor grade of sand or coarse aggregate used.

A source of supply for concrete materials in the area along the St. Lawrence river covered by this report, is of considerable importance, since if any large works of construction are to be carried on, concrete will, without doubt, be one of the principal building materials employed.

Cement

The question of the possibility of manufacturing cement in the district has already been considered in the section on Cement Making Materials, and will not be further dwelt on here.

Sand

The study of the sands available in the district, and the results of tests made on the samples collected, have already been referred to and tabulated in a previous section. From these results it can be stated that dune sands, terrace sands, or sands from the morainic sand ridges in the western end of the district, are totally unsuited by themselves for use in concrete. Beach deposits and deposits of fluvio-glacial origin sometimes yield sands which are suitable for use in concrete, although occasionally sands from the latter type of deposits are found to be extremely dirty, and wholly unsuited for concrete work. Unfortunately, most of the sand deposits in the district are of small extent; and, with the possible exception of the three deposits already mentioned, none of them are of sufficient size to warrant their being operated by a steam shovel.

It will, probably, be necessary, therefore, if any large construction work is contemplated, to rely on crushed limestone or sandstone screenings for the fine aggregate, unless sufficient material can be obtained from one of the three large deposits.

Coarse Aggregate

There are three possible sources of the coarse aggregate for concrete work in the district, namely, gravel deposits, field stones, and deposits of bed-rock.

Gravel Deposits

The gravel deposits of the district, although, generally, small in extent, contain considerably more material over ¼ inch size than under. It is question-

[1] Sand is frequently called the fine aggregate and generally includes all the material passing through the ¼″ mesh. Coarse aggregate is the name given to the gravel, or crushed stone, and generally ranges from ¼″ to 2½″ in size.

able, however, if it would be advisable to try to use the gravel of the district for large concrete work, since in any case it would have to be screened, and the larger material crushed before being used. It would be more economical to crush all the material needed, at some bed-rock quarry, and so be sure of obtaining material of a uniform grade. For small concrete structures, however, such as culverts, bridge piers, and local buildings, there are numerous deposits of gravel, which, by a little care in selection, will yield a suitable coarse aggregate.

Field Stones

The numerous morainic ridges throughout the district have varying quantities of loose stones and boulders scattered over their surfaces, also mixed with the clay or sand matrix of which they are composed. In some of the gravel pits the coarse material forms the greater part of the deposit. Materials from these two sources would have to be crushed and screened. The crushed stone and screenings obtained in most cases would be suitable for concrete structures but great care would have to be taken in respect to the material put through the crusher, since, among the field stones of the district, are occasional blocks of shale and other rocks that are badly weathered, which, if present in any quantity, would greatly weaken the mixture. R. H. Picher in his report on the road materials of Ontario[1] has covered the available deposits of field stone in a very complete manner, giving the approximate composition, together with an estimate of the amount of material available

Deposits of Bed-rock

For large works of construction in which concrete will play an important part, it will probably be necessary to utilize one or more of the quarries of limestone, or sandstone, for the supply of both fine and coarse aggregate. The first year's field work on this district showed that there was a scarcity of large deposits of gravel, and it was thought advisable to take samples of bed-rock for testing in the laboratory. One sample was taken from the sandstone quarry owned by W. A. Robert, Esq., Beauharnois, Que., and another from the limestone (dolomite) quarry owned by Mr. Francois Hebert, Maple Grove, Que. These quarries are described in the section of this report dealing with building stones.

The samples collected were blocks about 6 inches in diameter, and were crushed in the laboratory by hand, so that all would pass through a 2-inch screen. On account of the manner in which the samples were crushed there was practically no material finer than ¼-inch mesh. If they had been crushed in a crusher there would have been a considerable quantity of fines. The screen analysis of the two samples, after crushing, was as follows:—

	Sample of	
Mesh	Sandstone Per cent	Limestone Per cent
Retained on 2½"	42·7	....
2"	35·8	28·00
1½"	13·9	42·00
1"	3·1	20·00
¾"	2·0	4·66
½"	1·1	2·66
¼"	1·4	2·68
	100·0	100·00

[1] Mines Branch, Dept. of Mines, Bull. No. 32, pp. 23-33, 1920.

Cylinders of concrete were made, using the sandstone and limestone, respectively, for the coarse aggregate and standard Ottawa (Ills.) sand for the fine aggregate, with the same brand of cement in each case. The proportions used were:—

1 Cement.
3 Standard sand.[1]
5 Coarse aggregate.

Eight cylinders were made up: four with the sandstone as the coarse aggregate, and four with the limestone. Both ends of each cylinder were faced with ¼ inch of neat cement, to ensure a smooth bearing surface in the crushing machine. Two cylinders of each were broken at the end of 7 days, and the rest at the end of 28 days. The following results were obtained:—

	Sandstone		Limestone	
	7 days	28 days	7 days	28 days
	lbs. per sq. in.		lbs. per sq. in.	
8″ x 16″..	517	1,297	515	1,049
8″ x 16″..	499	1,140	494	862
Average..	508	1,218	504	956

Either of these stones would be suitable for use in concrete structures, and as the samples were fairly representative of their respective classes, it is safe to say that crushed rock suitable for use in concrete could be obtained from many of the quarries and rock outcrops which are to be found throughout the district.

LIME

The burning of lime has been carried on in the counties bordering the St. Lawrence since the first settlers began to build houses of stone and brick and to use whitewash. The remains of the crude pot kilns used for lime-burning are scattered all over the region. As boulders collected from the fields constituted the main source of supply of limestone the kilns were placed wherever convenient, and without reference, in most cases, to rock outcrops. The kilns were, generally, roughly built, and designed for a small output for local use only.

With the growing scarcity of wood for fuel, and the decline of building, these small kilns went out of use, and were allowed to go to ruin. By that time, too, owing to increased transportation facilities, lime was beginning to come in from more distant points where it could be made to better advantage than in the St. Lawrence district.

The largest kiln in the district was operated in conjunction with the extensive stone quarries north of Mille Roches, in Stormont county, Ontario. This was a draw kiln with masonry walls.

The collecting of scattered limestone boulders as the raw material for the production of lime cannot be considered feasible for a modern limeburning industry. It is necessary to find a suitable deposit of high grade limestone or dolomite, and to open it up by quarrying methods. Improved kilns of large capacity, fired with wood, coal, or gas, and continuous in operation, are necessary for a successful industry.

[1] By using the standard Ottawa (Ills.) sand which is a well rounded sand running between the 20 and 30 mesh, it is probable that the results of the crushing tests are considerably lower than they would have been if a well graded sand had been used.

Limestones show a considerable range of composition. Calcium carbonate is an essential constituent, and, in the case of a pure, high calcium limestone, the stone is composed almost wholly of this compound. Generally, a portion of the calcium carbonate is replaced with magnesium carbonate, in proportions ranging up to about 45 per cent magnesium carbonate, and 55 per cent calcium carbonate. As this limit is approached, the stone is termed dolomite. Impurities such as silica and silicates and compounds of iron and aluminium are almost invariably present.

Either high calcium limestone or dolomite is used for the production of lime for building purposes and in a number of manufacturing industries. The total percentage of impurities in the stone should be as low as possible, since they are decidedly objectionable in either industrial or building limes.

Within the area covered by this report, there are very few outcrops of limestone suitable for limeburning and these are probably limited to certain exposures of the Trenton and Black River formations which approach the St. Lawrence in the neighbourhood of Cornwall. On account of the thick covering of glacial drift which is so widespread over the region, the choice of stone is confined to a few outcrops, or to occasional localities where bed-rock can be obtained by the removal of a moderate amount of overburden.

The possibility of establishing a limeburning industry in this district is remote.

ROAD MATERIAL SURVEY IN BEAUHARNOIS AND CHATEAUGUAY COUNTIES, QUEBEC

Introduction

During the first half of the summer of 1919, the whole county of Beauharnois and the adjoining easterly portion of Chateauguay county were visited. This area lies to the south of the St. Lawrence river and extends from lake St. Francis to lake St. Louis. Valleyfield, the most important centre of the district, is situated opposite DeSalaberry island, at the head of Coteau, Cedar and Cascades rapids, 30 miles southwest of Montreal. The investigation was carried on with the object of obtaining information on the available road materials, and supplementing similar work done during previous years along the St. Lawrence river between Kingston and Montreal. The work consisted in mapping and examining every occurrence of bed-rock and all field stone deposits and in securing samples from the more important quarries for laboratory tests.

General Considerations

The general character of the country is a clay flat with occasional slight rises with boulder clay subsoil. The rock formations lie nearly flat and the overlying mantle of clay and boulder clay is generally thick, hence bed-rock outcrops are not frequent and, except in a few instances, do not present good opportunities for quarrying. The geological formations encountered are Potsdam sandstone and Beekmantown dolomite and magnesian limestones. The former extends as a narrow band from the international boundary through Chateauguay and the northeastern part of Beauharnois counties. The latter, more widely distributed, underlies the remaining portions of both counties. The boulder clay is seen along the St. Lawrence river, on DeSalaberry island, and in small patches in Beauharnois county, but the soil of the major part of the

district surveyed consists of stoneless clay. The land in both counties is very fertile and produces, especially, hay and oats. Truck farming is carried on to a certain extent near the town of Valleyfield, but Montreal is the main market for the farmer. The products are shipped by rail. Most of the main roads are now macadamized but they are often connected by stretches of clay roads almost impassable in wet weather. For this reason, and because of the absence of a connecting link with the system of good roads reaching Montreal, motor trucks are scarce and touring cars comparatively few, considering the importance of the counties.

Road Materials

The area surveyed is devoid of sand and gravel, but bed-rock and field stone constitute a sufficient supply of road material for local needs.

Bed-rock

Outcrops of dolomites and magnesian limestones of the Beekmantown formation are not frequent in the area surveyed, but are found at intervals. They have been quarried for building or crushed stone purposes at Bellerive (DeSalaberry Island), St. Timothée, St. Louis de Gonzague, Chateauguay, and Bellerive station. In every case, however, the quarries are of local importance only.

The stone is, as a rule, bluish-grey, fine-grained, and rather even in texture, and is generally fresh. It is less siliceous than the dolomite occurring north of the St. Lawrence river. The amount of weathered stone that must be rejected as road surfacing material is comparatively small. The top of the outcrops is weathered to a sandy, yellowish-brown, soft material but the weathering is generally limited to the upper layers of the formation.

This dolomite, or magnesian limestone, has given good service in the construction of water bound macadam, and upwards of 50 miles of such roads built throughout the two counties since 1915 have proved to be economical under the actual country traffic. Laboratory tests have shown that this stone has good road-making qualities. It is hard, tough, and has a good wearing quality. Its cementing value is known to be much lower than that of a pure limestone, but the present condition of the macadam roads referred to above, shows that it has more binding power than dolomite usually has. Being of good ability to stand abrasion under traffic, it does not yield a dusty and rutty road surface, but must be properly rolled in order to prevent a rough surface undesirable for steel tire vehicles.

Outcrops of Potsdam sandstone are fewer than outcrops of Beekmantown dolomite. Over the area examined this rock formation is heavily overlain with marine clay and in most occurrences the extent of the exposure is small. However, beds of Potsdam are more or less continuously exposed for a distance three miles west of the village of Beauharnois.

The stone varies in character from a hard, white, flinty sandstone to a soft, greyish-white, medium-grained sandstone much shattered in places and stained with iron. The more important openings are those at the Euclide Montpetit quarry, where the sandstone has been extensively quarried for dimension stone, rubble, and crushed stone for concrete aggregate. Most of the material is soft and should not be used in roadwork, but the harder type

can be advantageously used in the construction of road foundations and drains. Because of its non-binding property, however, even the hardest variety of this rock cannot be considered as road surfacing material.

A brief description of the deposits of bed-rock that were seen is given below, and in Table IV will be found the results of laboratory tests upon samples collected from the more important quarries.

Deposits of Bed-rock

BEAUHARNOIS COUNTY

No. 1.—DeSalaberry island, immediately north of the town of Bellerive. Quarry owned by M. Lapierre. Formation: Beekmantown dolomite. Bluish-grey, even, fine-grained dolomite, weathering to yellowish-brown. The stone is particularly fresh, hard and tough, breaking with conchoidal fracture. The pit is 72 yards by 50 yards by 2 yards = 7,200 cubic yards in size. Workings for building stone have progressed in two benches facing east. Three beds, 6 to 18 inches thick are exposed. They dip slightly to the southwest and strike east 25 degrees south, with vertical joints, 3 to 5 feet apart, trending south 20 degrees west and east 25 degrees south. The beds are massive and less fractured than those in the occurrences. More stone can be obtained but not without stripping an overburden of 3 to 4 feet of boulder clay. The quarry floor is below ground-water level, and drainage by pumping is necessary. Further development is possible to the west and north of the actual opening but in the latter case only over a distance of a few hundred feet. This is about the best road-making stone to be had in the neighbourhood of Valleyfield. Results of laboratory tests upon samples collected are given in Table IV, No. 1.

No. 2.—DeSalaberry island. Northwestern town limit, Bellerive. Owner: Magloire Theoret. Beekmantown dolomite. Quarry located just north of Grand Trunk Railway track, including several old openings formerly known as Simpson's quarries which are now filled with debris and tailings. About 10 feet of stone is exposed on the western wall of a crescent-shaped pit. The stone ranges from light grey, compact to fine-grained, steel-blue, with irregular, wavy streaks of darker material. It occurs in thin, irregular beds, separated by thin layers of clay and shale. The fresh material is tough but a good deal of the stone in the upper layers is much weathered. The beds vary from 2 to 7 inches in thickness and are nearly flat lying with irregular wavy bedding planes. They are moderately jointed at various angles. The deposit forms a ridge running east-west, approximately 250 yards by 100 yards in extent, with its highest point about 10 feet above the surrounding surface. The overburden ranges from 2 to 3 feet and consists of boulder clay. More stone can be had without difficulty from the northern edge of the ridge where it forms an escarpment, but in order to get fresh material quarrying will have to proceed to a lower level than the foot of the ridge. Crushed stone obtained here is being used for road work in Bellerive. Service as well as laboratory tests have shown that this stone has very good wearing quality. See results of tests in Table IV, No. 2.

No. 3.—North shore of DeSalaberry island. On the property of Mr. A. McSheen, outcrops of Beekmantown dolomite occur along the river shore for a short distance, about opposite Coteau rapids. In a small opening 4 yards by 5

yards, there is an exposure of 3 to 5 feet of stone resembling that described in No. 1. The chances for future development are poor on account of a thick overburden and because the top of the outcrop is nearly level with the river.

No. 4.—St. Louis de Gonzague. One and one-half mile west of village, concession VI. Property of Arsène Meloche. Outcrops of Beekmantown dolomite exposed along a low ridge on the south side of the road. Exposure of 5 feet of stone in an excavation measuring 50 yards by 30 yards. Thin bedded steel-grey and fine-grained dolomite with irregular streaks of darker coloured material. The stone is fairly fresh excepting one foot at the top which is weathered to brownish. Flat lying beds separated by thin layers of clay and shale. Breaking joints are frequent and in various directions, but the stone is not shattered and a good crushed product can be obtained. The overburden, consisting of boulder clay and carrying weathered blocks from the upper beds, is from 3 to 6 feet thick. The deposit forms a slight elevation trending nearly east-west for a distance of about one hundred yards and rises to approximately 10 feet above the surrounding country. (Plate XXIX.) Water-bound macadam road built with material from this quarry was found in fair condition after 5 years of service and the dolomite apparently had enough binding power to wear down to a smooth surface. Shallow ruts had formed in the road but it was dustless and the interstices between the road crust aggregate were well filled with cemented powder. Stone tested. See Table IV, No. 4.

No. 5.—St. Louis de Gonzague, Conc. VII. Doubtful outcrops of Beekmantown dolomite. Low ridge showing half buried blocks just north of St. Louis road and extending in a northeast direction from Durham road for about one-quarter mile. Overburden apparently is light.

No. 6.—St. Stanislas-de-Kostka. Beekmantown formation. Immediately north and south of the village two outcrop areas form hillocks of small extent. The stone, which is mostly covered, is sandy dolomite weathered to a dark colour on the surface. The facilities for quarrying are not good.

No. 7.—Two miles northwest of St. Stanislas-de-Kostka, outcrops of Beekmantown dolomite occur over an area 70 yards by 50 yards in extent between the river road and lake St. Francis. The deposit forms a round-topped hillock 6 to 8 feet high and partly covered with a light overburden. The stone on the surface is much weathered.

No. 8.—St. Timothée. Quarry owned by Wilbrod Breault and Alexis Dorais. Beekmantown formation. One quarter mile southwest of the New York Central Ry. station along the edge of a bush there is a quarry 60 yards by 45 yards by 3 yards = 8,100 cubic yards, from which stone has been taken for road metal. Dolomite is exposed to a depth of nine feet, an ascending section of which is as follows:—

(*a*) Dark-grey, medium-grained, siliceous dolomite, in rather massive beds. fresh—3 feet.
(*b*) Thin-bedded, light grey, compact, splintery, fresh dolomite—1 foot.
(*c*) Irregularly thin-bedded, shaly and weathered dolomite with streaks, up to 1 inch thick, of black cherty material—1 foot.
(*d*) Massive, fine-grained dolomite with geodes of secondary calcite—1 foot.
(*e*) Irregular beds, dark coloured, partly shaly, partly sandy, much weathered and shattered—3 feet.

The outcrops are seen over an area of approximately 500 yards by 300 yards partly covered with a light overburden. They form a noticeable ridge, immediately north of road, from which several thousand cubic yards of fairly good road stone are to be had. Further quarrying will involve a certain amount of stripping but there will be no drainage trouble, the actual quarry floor being above ground-water level. Some of this stone has been used in the construction of water-bound macadam roads in the parish of St. Timothée. After 3 years of service under medium traffic these roads were in good condition. One sample was collected and has been tested. See Table IV, No. 3.

No. 9.—Two miles southeast of St. Timothée village, con. I and II, outcrops of Potsdam sandstone, covering an area of three-quarter mile by one-half mile. extend along both sides of the road. White to greyish sandstone, iron stained, soft and partly weathered on the surface. Too soft to be used as road metal.

No. 10.—Immediately east of the sandstone outcrops above described, there is an occurrence of Beekmantown dolomite on the farm of Mr. Lauzon, a few hundred feet north of the road. About 5 feet of thin-bedded stone is exposed in an old excavation measuring 30 yards by 15 yards. Bluish-grey, sandy dolomite of sugary texture and weathered on the surface to a depth of one to two inches. A renewal of operations is possible advancing southward from the actual opening, but the overburden may reach several feet of boulder clay carrying many large boulders. However, a few thousand cubic yards of stone can be had without much trouble. This stone resembles in character some of the dolomite occurring in No. 8, and its value as road material may be compared to that rock.

Potsdam Sandstone Formation

Village of Beauharnois. Bare outcrops of sandstone are exposed along the St. Lawrence river, west of the village of Beauharnois, for a distance of three miles. The stone has been worked at several places, but the most important openings are located at the west end of the outcrops near Melocheville.

These are owned by Euclide Montpetit. The quarried beds form an escarpment to the south of the river road and are exposed to a depth of from 10 to 15 feet along a working face 250 yards in length. The beds are practically horizontal and badly shattered. They consist of interbedded white flinty and greyish-white, fine to medium-grained sandstones, spotted with brown oxide of iron and containing pockets of coarser grained quartzitic material. Large quantities of stone were obtained here for rough building and crushed stone.

A good section of the sandstone formation is also exposed at the falls on river St. Louis, immediately west of the village of Beauharnois, where a hard white flinty variety of the sandstone predominates. The amount of available material in this deposit is great, but it is a poor road metal, and should not be used except with a bituminous binder.

Sample tested. See Table IV, No. 5.

CHATEAUGUAY COUNTY

Bellevue sta., Ville de Lery. On the farms of Messrs. Alphonse and Donat Faubert, Beekmantown formation. Outcrops of dolomite along the northern edge of a ridge running parallel to and just south of the New York Central Ry. Bed-rock shows at intervals for a distance of 200 yards but is covered to the south with a thick clay terrace.

Small openings have been made for rough building stone on Mr. Alphonse Faubert's farm, and for road metal on the next lot to the west owned by Mr. Donat Faubert. The stone at the two places is identical. It is bluish, siliceous, fine-grained dolomite, rather even in texture. At one place 5 feet of it is exposed. The stone is fresh except in the upper layer where about one inch of the surface is weathered to yellowish-brown. More stone can be obtained without drainage trouble by quarrying along the northern edge of the outcrops where a 10-foot working face is possible. Operations, however, could not advance far to the south on account of the heavy overburden. The amount of available stone may reach a few thousand cubic yards. Only a small quantity of this stone has been used for road building. Loose or fence stone, resembling it very much in character, but somewhat weathered on the surface, has given satisfactory results in water-bound macadam on the river road.

Stone tested. See Table IV, No. 6.

Chateauguay. One-half mile west of the village. Laberge quarry. Beekmantown dolomite and magnesian limestone. Quarry measuring 75 yards by 50 yards by 5 yards = 18,750 cubic yards, located to the south of the Chateauguay-Woodlands road. Two working faces have progressed in southerly and southwesterly directions, the face in the latter case being developed in two benches. A total height of wall of over 20 feet is reached, but the deeper part of the quarry is covered with 6 to 8 feet of standing water.

The character of the stone is rather uneven. It varies in texture from fine- to somewhat coarse-grained. It is darker in colour and much less siliceous than the dolomite in Beauharnois county. The coarse-grained variety, which looks more like magnesian limestone, occurs in the lower 10 feet of the quarry wall, while the finer and more even-grained dolomitic stone overlies it. The latter type shows a good deal of lamination, carrying numerous thin black shaly partings along the bedding planes. It is as a rule more irregularly and much more thinly bedded than the lower stone. The formation is nearly flat lying, with a good deal of fracturing in various directions. (Plate XXX).

The outcrops extend over an area about one-half mile square and rise to approximately 20 feet above the surrounding ground forming a small escarpment where they are quarried. Much more stone is available without difficulty in quarrying.

This material does not give as uniform a crushed product as that from the deposits described in Nos. 1, 2, 4, but laboratory tests made upon one sample collected have proved that in percentage of wear and toughness it resembles the dolomite from near St. Timothée. Results of laboratory tests on sample are given in Table IV.

Outcrops of Beekmantown dolomite are seen at a point on Chateauguay river, just north of Primeauville. The location of the occurrence, however, is very unfavourable for future development.

Beekmantown formation. Outcrops of bed-rock are exposed on both shores of Chateauguay river, one-half to one mile south of the village; but the chances for quarrying are poor as they occur at a level below high water mark.

TABLE IV

Results of Tests on Bed-rock

CHATEAUGUAY AND BEAUHARNOIS COUNTIES, QUE.

Locality	Rock type	Physical Properties					
		Per cent of wear	French coef. of wear	Toughness	Hardness	Specific gravity	Absorption in lbs. per cu. ft.
Lapierre quarry, Bellerive.	Beekmantown dolomite	1·86	21·6	24	18·1	2·74	1·04
Mngloire Theoret quarry, Bellerive..	"	2·50	16·0	21	16·1	2·79	0·40
Alexis Dorais quarry, St. Timothée..	"	3·06	13·1	14	16·1	2·85	0·57
Arsène Melcche quarry, St. Louis de Gonzague	"	2·58	15·5	25	17·8	2·76	0·62
Montpetit quarry, Beauharnois.	Potsdam sandstone.......	2·34	17·1	6	17·3	2·65	0·74
Alphonse Faubert's farm, Bellerive Station, Ville de Lery....................	Beekmantown dolomite.......	2·30	17·4	23	18·0	2·74	0·32
Laberge quarry, Chateauguay	"	2·38	16·8	15	18·2	2·77	0·38

Field Stone

Field boulders piled in fences, or scattered in the fields are not plentiful in Beauharnois county, but they are generally to be found at intervals within short hauling distance of the roads. In Chateauguay large quantities lie along the river shore from the western boundary of the county eastward through Boisbriand and Pointe-Mercie, to a point beyond Woodlands; but it is doubtful if in these summer resorts, the owners would permit the removal of stone fences for road building while quarried stone can be had nearby. In the neighbourhood of Chateauguay village and south of it field boulders are scarce.

The aggregate in each of the above mentioned occurrences does not vary much in character. It is composed, in varying proportions, of three main types of rock: Beekmantown dolomite and magnesian limestones, Potsdam sandstones, and igneous rocks which are mostly gneisses. As a rule dolomites predominate in the composition of deposits in the western part of the area surveyed. Sandstones, except in occurrences between St. Timothée and Beauharnois village where they form the bed-rock, constitute from 15 to 40 per cent of the total yardage of the aggregate. The boulders of igneous origin, which are chiefly gneisses but also include some granites, syenites, quartzites, anorthosites, etc., are uniformly distributed, but in comparatively small quantities.

Composition estimates of each deposit are given in Table V. As to the relative road making quality of the aggregate in any locality, it can be calculated, if the average wearing value of each rock species and its relative proportion in the combination are known: Thus, if the percentage of wear of the various species are expressed by $W_1 W_2—W_n$ and the percentage proportions in which they occur in the mixture $C_1 C_2—C_n$, the per cent of wear of the mixture W_m is given by the formula $W_m = \frac{\Sigma CW}{100}$.

It was found in previous surveys where field boulders resemble in character those of this district that the average per cent of wear of each species is as

follows: Beekmantown dolomite 3·3 per cent, gneisses 3·0 per cent, Potsdam sandstone (hard, fine-grained type) 2·2 per cent. The coarse-grained Potsdam sandstone is known to have a high per cent of wear and is not suitable for road construction.

TABLE V

Character of Deposits of Field Stone

Location	Average of Whole Deposit					Remarks
	Per cent of			Per cent stone over 1 ft. diameter	Total yardage	
	Dolomite	Igneous	Sandstone			
DeSalaberry island, along north shore road.	45	15	40	35	800	Dolomite is weathered on the surface but fairly fresh inside. Sandstone is soft and a poor road material.
Northeast end of DeSalaberry island.	50	10	40	50	1,000	Igneous is largely composed of gneisses.
Stock piles along road north of Bellerive.	60	10	30	0	100	About 50 per cent of the sandstone is very soft. The dolomite is fairly fresh.
	45	5	50	0	125	
Parish of St. Timothée, south of village.	65	5	30	33	1.500	Dolomite is fine-grained, bluish-grey, somewhat weathered to brownish colour on the surface. It has been used with success in macadamizing work. Both the soft friable and the tough quartzitic varieties of the sandstone occur in about equal amount. The latter can be used with advantage in foundation work.
Parish of St. Timothée, con. I and II, west of station road	70	5	25	33	1,800	
Parish of St. Timothée, con. II, east of station road.	65	5	30	30	2,500	
Parish of St. Timothée, con. I and II.	20	0	80	50	2,000	
Parish of Ste. Madeline, con. II and III, from N.Y. Central R. line to G.T.R. line.	55	5	40	20	5,000	Dolomite partly fresh, partly weathered. Sandstone is soft.
Con. IV, 4 miles south of Valleyfield.	60	0	40	10	900	
Parish of St. Louis de Gonzague, west of village, con. VI and VII.	60	5	35	15	8,000	
South of village of St. Stanislas-de-Kostka..............	75	5	20	20	1,500	
Con. IV and V, 3 miles southeast of St. Stanislas......	85	5	10	20	2,500	
1½ mile west of village of Beauharnois................	5	5	90	25	1,500	
Along lake shore from 2 miles east of Beauharnois to Woodlands in Chateauguay county	80 100	0 to 5	0 to 20	20	....	The amount of field boulders, not estimated, on account of the built up character of the area where they occur, not less than 20,000 cubic yards.

CHAPTER V

DATA FROM WELL RECORDS, DRILL CORES, AND OTHER SOURCES

General Statement

During the course of this investigation, considerable data were obtained relating to the depth of the overburden, the general configuration of the rock surface, and the character of the bed-rock. While much of this information was of a general nature, and referred to isolated areas, some of it is considered of sufficient importance for a place in this report.

Overburden

The overburden covering nearly the whole of the area mapped, is composed of glacial drift, or material derived from it, and by far the greater part of it is boulder clay, marine clay, or silt. The characteristics of these different classes of materials have already been described. A few words, however, are necessary as to their suitability for foundations, canal banks, dam construction, and other uses.

The boulder clay, or hardpan as it is more commonly known to civil engineers and contractors, is in nearly every case a suitable material for foundation work, or canal banks. It compacts well, and is practically impervious to water, especially in the district east of Cardinal. Another point in its favour is, that it is the lowest member of the Pleistocene series, and consequently rests directly on the bed-rock. With the exception of bed-rock it is the most suitable of all the different strata in the whole district for the above purposes.

The marine clay when not underlain by silty clay is also a fairly suitable material for foundation and constructional work, as it is more impervious to water seepage than the boulder clay. It is, however, in nearly all parts of the district, underlain by a silty clay, which, when wet, is very liable to cause the stiffer and more compact marine clay to slip or slide along the contact between the two materials. This slipping, or sliding, due to the lower silty clay becoming saturated with water, and forming practically a quicksand, takes place along the banks of the St. Lawrence river on the north shore, a few miles to the east of Cedars, Que. (See Plate VI.) It is evident that the banks of a canal excavated in stiff marine clay lying directly on boulder clay or bed-rock, hold their position better than if a layer of silt lies beneath the stiff clay.

The depth of the overburden varies greatly over the whole area. In some parts of the district, rock outcrops at the surface, or the overburden is very thin, while in other localities the unconsolidated mantle, in places, extends to a depth of 115 feet, and even deeper. The average depth of unconsolidated material would be about 40 feet, if spread uniformly over the whole of the rock surface.

Near Prescott, Ont., the overburden of drift is, on an average, comparatively thin, and rock outcrops in this area are fairly numerous. In the intermorainal area, in Matilda and Williamsburg townships, Dundas county, and Osnabruck township, Stormont county, the drift covering is considerably thicker, in some places attaining a depth of 70 feet or more. In the bed of the St. Lawrence, at Morrisburg, where the Ontario Hydro-Electric Commission drilled 40 holes, the average depth of overburden resting on the rock is 41 feet.

The drift covering is very unevenly distributed over Cornwall township, Stormont county, and in Charlottenburg township, Glengarry county, where the Cornwall morainal belt is best developed. The ridges of drift in this region are high but the bed-rock is only a few feet below the surface of many of the depressions between the ridges.

The territory included in the eastern end of the Cornwall map sheet and in the Valleyfield sheet is covered principally by marine sediments, that are in most cases of considerable thickness, especially in the eastern end of the area mapped. Some drilled wells in Soulanges county, Que., for example, are reported to have penetrated about 150 feet of marine clays and silts before bed-rock was encountered. A noticeable feature of the Valleyfield area and one that holds true for practically all the area included in the Valleyfield map sheet, is, that whenever boulder clay is encountered, bed-rock is relatively near the surface.

Configuration of the Rock Surface

The rock surface over the whole area mapped, as far as could be ascertained, is comparatively flat, with only slight undulations here and there. Much of the rock surface exposed shows glaciation; and it is probable any pronounced inequalities which there may have been originally in the rock floor have been removed by that agency.

It is possible that there may be some preglacial stream gorges not obliterated by glacial erosion and buried beneath the glacial drift, but the boring done so far has not revealed them.

The data obtained up to the present refer mostly to the St. Lawrence River bed and to areas near the river to which it would be advantageous to divert the existing canal if the proposed work for a deeper waterway and the development of waterpower is carried on.

Several borings have been made between Prescott and lake St. Louis under the direction of Mr. D. W. McLaughlin of the Railways and Canals Department. The borings were not made at regular intervals along the river, but were grouped at certain points where construction is considered necessary, and at some of these places the surface of the bed-rock beneath the drift cover is well defined as a result of this work.

The borings in the bed of the St. Lawrence river at Morrisburg, Ont., by the Hydro-Electric Commission and the borings in the vicinity of the power plant of the Cedar Rapids Manufacturing and Power Company at Cedars, Que., give the depths at which bed-rock was encountered at these localities.

The average height of the rock surface in the river bed in the neighbourhood of Prescott, Ont., is about 215 feet, and at Cascades Point, Que., 87 miles east, it is 67 feet above sea level. The river descends between these levels by a series of steps placed at irregular intervals, and at most of these points bed-rock is found closer to the river bed than in the intervals between them.

The remnants of a rock escarpment can be traced for a short distance along the north side of the St. Lawrence east from Prescott. The profile of this escarpment from the river bottom at Morrisburg, Ont., to the rock outcrop at Bouck's Hill, 8 miles to the north, and the drift cover on the bed-rock is shown in Fig. 4.

The field work done by Mr. J. A. Robert in Soulanges and Beauharnois counties, Que., gives a good deal of information about the rock surface beneath

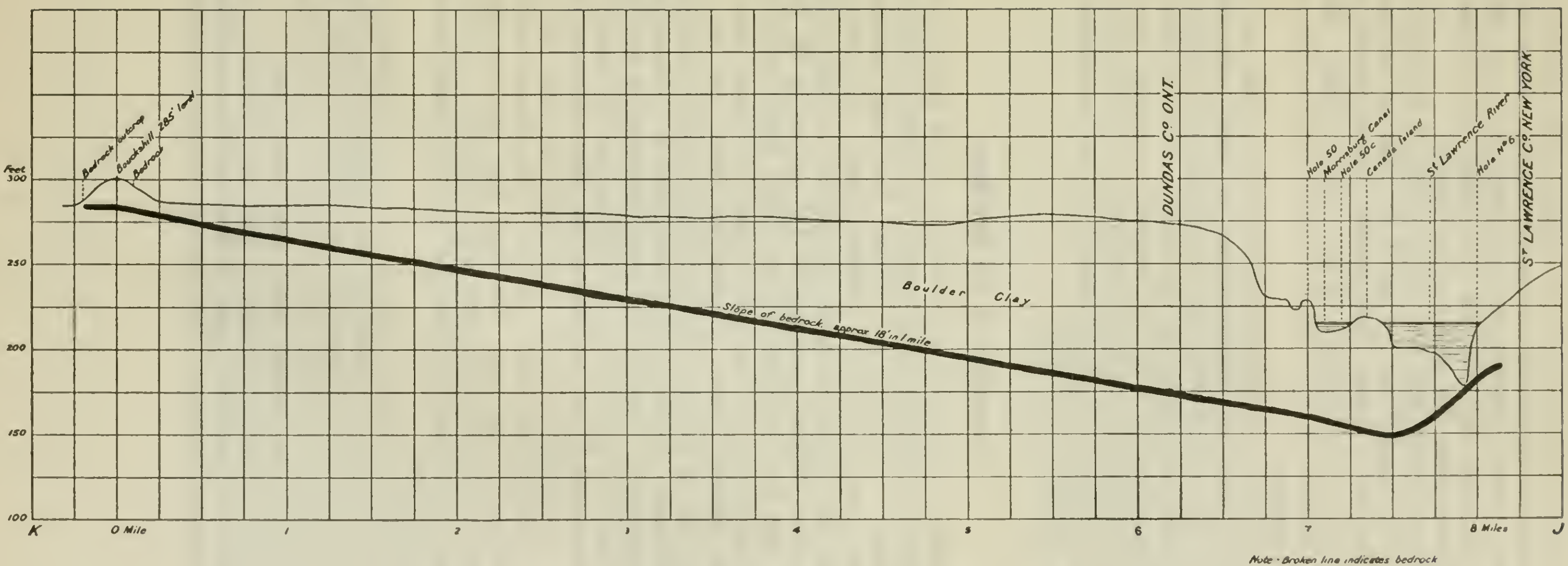

Fig. 4. Transverse section J-K across St. Lawrence valley.

the wide, flat, drift-covered areas in that region, which has been incorporated in the four sections accompanying this report (Fig. 5). Some of these sections show the contrast existing between the undulating top of the bed-rock and the flat surface of the land, and illustrate very clearly the levelling done by the sediments laid down when this land was sea bottom.

The sections also show that the course of the St. Lawrence river is controlled by the drift deposits and its bed is not sunk at the places where the surface of the bed-rock is lowest. This feature is most marked in the case of the rock depression five miles north of the river at Cedars, Que., where the bottom of the depression is about 70 feet lower than the rock surface in the bed of the St. Lawrence.

As already stated the occurrence of boulder clay patches and boulder ridges in this district indicates the presence of rock very close to the surface, but the rock floor under the marine sediments surrounding these patches is generally lower. The sections are drawn on too small a scale to show this relation clearly, but by comparing the maps and sections, it becomes more evident.

In many of the areas in Ontario the presence of bed-rock at or near the surface is usually indicated by the occurrence of numerous slightly worn blocks of limestone or dolomite in the drift.

Character of the Bed-Rock

The information relating to the character of the bed-rock obtained from the rock exposures and quarries of the district, has already been given in other parts of this report. Further data, however, have been collected from drill cores which have been recovered at different times. The principal cores to which the writers had access, were those obtained by the Ontario Hydro-Electric Commission, in their drilling operations in the bed of the St. Lawrence river at Morrisburg; and those recovered by the Cedar Rapids Manufacturing and Power Co., in the vicinity of their power plant at Cedars, Que.

The Ontario Hydro-Electric Commission, during the last 3 years, has been testing the bed of the St. Lawrence river between Morrisburg and the New York state shore. About 40 holes were bored by diamond drills and the writers were requested to examine the cores and tabulate the different rocks encountered. This work was done in Morrisburg, and the detailed descriptions of the cores are now on file in the office of the Mines Branch, Department of Mines, Ottawa. Excepting in two or three holes, the rock was penetrated in each case to an approximate depth of 40 feet. The deeper holes were carried to a depth of 70 feet, in the rock. The cores show that the bed-rock is composed principally of dolomite and magnesian limestones, with a few narrow bands of dark-grey shale, and thin films and layers of shale scattered through two of the dolomite beds.

The dolomite beds are very compact and mostly fine-grained, but they vary in texture from granular or sandy to very fine-grained and flinty. A small proportion of the granular rock appears to be pitted, but as the pits, or pores are closed, the portion of the rock mass in which they occur does not necessarily form a porous layer through which water would flow.

Although some of the beds contain a high percentage of lime carbonate and are probably true limestones, most of them contain considerable amounts of magnesium carbonate associated with the lime carbonate, and may be called

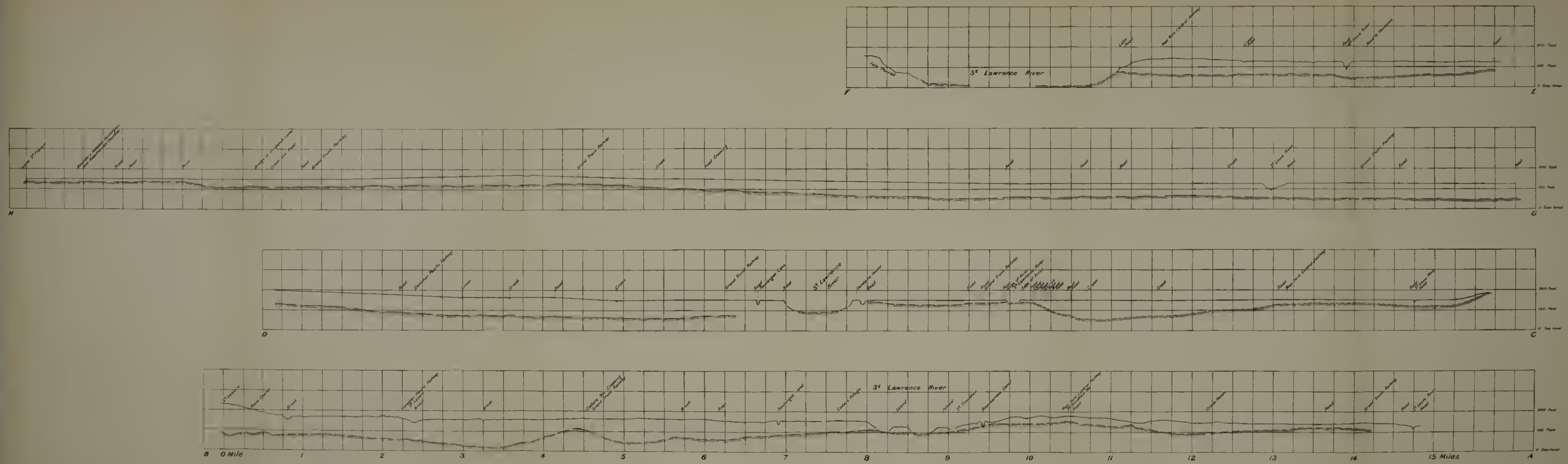

FIG 5

SECTIONS SHOWING DEPTH TO BEDROCK BELOW SURFACE
IN HUNTINGDON, BEAUHARNOIS AND SOULANGES COUNTIES, QUEBEC.

Note - Broken line indicates bedrock

Sections prepared by J A Robert B A Sc
Borings Division Department of Mines

magnesian limestones. When the percentage of magnesium carbonate becomes high enough in proportion to the lime carbonate they are known as dolomites.

It should be noted that variation in the chemical composition of the rock does not necessarily affect its physical character, for dolomites are often to be preferred to limestones for certain classes of structural work.

The dark shales are slaty rather than shaly in character as they do not slake in water even when crushed and ground. A clay shale slakes readily and becomes plastic under this treatment.

The 40-foot section of rock revealed by the drill cores shows no defects whatever from an engineering standpoint, and while there are only two or three drill holes which extend to a depth of 70 feet, the rock in these cores is the same.

There is no trace of weathering, the top of all the cores being just as fresh and unweathered as the bottom.

There are no open seams or cracks, either vertical or horizontal. Each bed or layer of rock is solidly welded to the layers above and below it and the vertical joint planes are tight and impervious.

Very little siliceous material is present; consequently, there are no sandstone beds or layers which might be porous, but not necessarily so.

It would be difficult to find a better bed-rock than this for dam foundations and water storage.

For the purpose of description, the beds encountered in the drilling were classified as follows: Drillhole No. 31 being used as a typical example of the 40-foot holes, and Hole No. 7B as representative of the deeper holes.

Classification and Details of Drillings

Class I—Light Grey Dolomite

This material consists of all the light coloured, fine-grained, compact dolomite, strongly resembling lithographic stone in appearance.

Class II—Grey Dolomite

Under this class is grouped all the grey, fine, medium or coarse-grained rocks, either dolomitic or calcareous. The rock varies in texture from very dense compact, fine-grained, to coarsely crystalline, with calcite seams or small cavities lined with calcite crystals or pyrite.

Class III—Dark Grey Dolomite

The difference between the material grouped under this class and that in Class II is one of colour only; otherwise the description for the grey rock will hold for this. The material grouped under this class is considerably darker in colour; and since many of the dark beds are persistent through a number of holes, it was thought better to separate them in order to help in identifying the different beds.

Class IV—Shaly Dolomite

Under this class is grouped all the material which contains shaly partings, and all dolomite which has a tendency to a shaly structure. It varies from light to dark in colour and from coarse to fine in texture.

Class V—Shale

These beds consist of the true shale bands, which are of sufficient size to note.

HOLE No. 31

Locality.—In the bed of the St. Lawrence river, off southeast corner of Canada island.
Depth of Water.—5 feet 9 inches.
Elevation Ground Surface.—208·09 feet above sea-level.
Ground Penetrated.—38 feet ¼ inch.
Elevation of Rock Surface.—170·07 feet above sea-level.
Rock Penetrated.—41 feet ¼ inch.

0′ 0″— 1′ 6″	Fine-grained, compact, grey dolomite
1′ 6″— 6′ 2″	Fine-grained, dark grey dolomite
6′ 2″— 8′ 0″	Medium-grained, light grey dolomite
8′ 0″—11′ 0″	Fine-grained, compact, dark grey dolomite
11′ 0″—12′ 0″	Medium-grained, shaly, dolomite (dark grey), with calcite
12′ 0″—13′ 6″	Fine-grained, grey, compact dolomite
13′ 6″—14′ 0″	Black shale band
14′ 0″—15′ 4″	Fine-grained, dark grey dolomite
15′ 4″—16′ 4″	Fine-grained, compact, grey dolomite
16′ 4″—26′ 9″	Fine-grained, compact, light grey dolomite
26′ 9″—27′ 5″	Fine-grained, compact, grey dolomite
27′ 5″—27′ 7″	Black shale band
27′ 7″—29′ 10″	Fine-grained, compact, grey dolomite
29′ 10″—31′ 2″	Fine-grained, compact, grey dolomite with calcite seams and patches
31′ 2″—33′ 0″	Fine-grained, compact, dark grey dolomite
33′ 0″—36′ 4″	Fine-grained, compact, grey dolomite
36′ 4″—37′ 10″	Medium-grained, grey dolomite, with calcite patches
37′ 10″—41′ 0¼″	Fine-grained, compact, dark grey dolomite

HOLE No. 7 B

Locality.—In channel between Clark island and U.S. mainland.
Depth of Water.—32 feet 8 inches.
Elevation of Ground Surface.—181·88 feet above sea-level.
Ground Penetrated.—1 foot.
Elevation of Rock Surface.—180·88 feet above sea-level.
Rock Penetrated.—77 feet 3¾ inches.

0′ 0″— 5′ 0″	Dark grey, granular dolomite
5′ 0″—10′ 0″	Grey dolomite, very compact
10′ 0″—11′ 6″	Grey dolomite, very compact, fine-grained and banded
11′ 6″—14′ 0″	Grey dolomite, very compact
14′ 0″—15′ 0″	Dark grey, shaly dolomite
15′ 0″—21′ 0″	Compact grey dolomite
21′ 0″—26′ 0″	Compact grey dolomite, banded
26′ 0″—32′ 8″	Dark grey, shaly dolomite
32′ 8″—40′ 0″	Fine-grained, flinty, grey dolomite
40′ 0″—46′ 0″	Fine-grained, compact, grey dolomite
46′ 0″—49′ 2″	Dark grey, shaly dolomite
49′ 2″—55′ 0″	Grey dolomite, fine-grained, compact, with calcite seams and patches
55′ 0″—56′ 0″	Grey, flinty dolomite
56′ 0″—63′ 0″	Grey dolomite, fine-grained, with calcite seams
63′ 0″—63′ 8″	Grey, flinty dolomite
63′ 8″—66′ 0″	Grey, granular dolomite, with numerous cavities and calcite seams
66′ 0″—68′ 6″	Grey dolomite, compact, and fine-grained
68′ 6″—70′ 0″	Grey granular dolomite, with cavities and calcite seams
70′ 0″—73′ 6″	Grey compact dolomite, with cavities and calcite seams
73′ 6″—77′ 3¾″	Light grey, flinty dolomite

A few ostracods were the only fossil remains that could be detected in the above core.

There are no sandy beds in the lower portion of the core, and no indication that coarse siliceous sediments are coming into this portion of the beds.

In the vicinity of the power plant of the Cedar Rapids Manufacturing and Power Company, at Cedars, Que., a number of drill holes have been put down, both in the bed of the river and on the shore. The writers were permitted to inspect these cores, and the following log of one of the wells will illustrate the character of rock encountered in that district:—

HOLE No. 6 (Power House)

Location.—Near southeast corner of new power house.
Elevation of collar of hole.—125 feet.

0′ 0″— 7′ 0″	Clay and boulders
7′ 0″— 8′ 3″	Loose, shattered rock
8′ 3″—14′ 10″	Hard sandstone, light in colour, with rounded grains and calcareous bond
14′ 10″—17′ 7″	Dark grey dolomite
17′ 7″—24′ 6″	Medium-grained sandstone, with rounded grains
24′ 6″—25′ 9″	Dark grey, crystalline dolomite
25′ 9″—31′ 0″	Compact, greyish-white sandstone. At 28′ 6″ there is a 6-inch seam of coarse, sugary sandstone, without any bond. This material is porous and carries water.
31′ 0″—32′ 6″	Fine-grained, dark grey, crystalline dolomite
32′ 6″—37′ 6″	Greyish-white porous sandstone, calcareous bond, and rounded grains
37′ 6″—37′ 9″	Fine-grained, compact, dark grey dolomite, with sandy inclusions
37′ 9″—38′ 0″	Fine-grained, compact, greyish sandstone
38′ 0″—40′ 0″	Fine-grained, compact, light grey, crystalline dolomite
40′ 0″—41′ 0″	Dark grey, calcareous sandstone
41′ 0″—41′ 8″	White sandstone, rounded grains and calcareous bond
41′ 8″—41′ 11″	Dark grey, coarse-grained dolomite
41′ 11″—42′ 8″	White sandstone, rounded grains and calcareous bond
42′ 8″—42′ 11″	Dark grey, coarse-grained dolomite
42′ 11″—43′ 11″	Dark grey, calcareous sandstone
43′ 11″—47′ 9″	Fine-grained, whitish compact sandstone, calcareous bond
47′ 9″—50′ 0″	White, porous sandstone, with rounded grains and calcareous bond

CHAPTER VI

INDUSTRIES

General Statement

The industries which may be based on the raw materials available in the district are those using silica, lime, clay, sands, and gravels.

The silicate industries include cement, clay products, silica sand, sand-lime brick, artificial stone, glass, carborundum, etc.

The lime using industries include the production of lime for various purposes, as fertilizer, building material, paint, etc., or for the manufacture of cement.

The opportunities for establishing cement plants or limeburning industries have already been indicated under the sections on "Cement Material" and "Lime".

SILICATE INDUSTRIES

The raw materials found in the district covered by this report, which could be employed in the silicate industries are sandstone, sands and gravels, and clays. The occurrences of these materials are all shown on the accompanying maps, and descriptions of the several deposits are to be found elsewhere in this report. Brief descriptions of the methods of using these materials in the several industries follow.

Clay-Working Industry

Historical

A number of small plants made soft mud building brick at various points along the St. Lawrence river in former times. These plants were located at Prescott, Cardinal, East Williamsburg, Aultsville, Santa Cruz, Dickinson Landing, Moulinette, Cornwall, and Lancaster, in Ontario, and at the village of Beauharnois in Quebec.

They were all small plants, making soft mud brick by hand, or with horse, or steam power driven brick machine. The drying was done on open floors, or on racks and pallets built out of doors. The bricks were built up in scove or clamp kilns for burning, and the fuel used was wood. The output was small, probably a million bricks a year would be the greatest for one plant, and in many cases half that quantity, or less.

None of these brickyards are in operation at present, in fact it would be difficult to find the sites of several of them.

Bricks, however, were extensively used in building up the towns and villages, and in places like Prescott, Morrisburg, and Cornwall, the majority of the shops and houses are built of the red brick made in the vicinity. Many of the farm houses along the roads are also built of red brick.

Some of the red brick buildings were erected 80 years ago, and are still intact as far as the bricks are concerned. Weather seems to have very little effect on them and there are few buildings in which the bricks are spalling.

Some of the brickyards had an underclay that burned to a cream or buff colour, so that they were able to make two classes of brick, but there does

not seem to have been much demand for the buff coloured brick. Occasionally they were used for trimming around doors and windows, or at the corners of houses. The best example of the use of buff bricks is the Methodist church at Moulinette, which was built about 100 years ago, and remodelled in 1871, by having 8 feet taken off the height. The bricks were made water struck; they are a little smaller than the standard size, and burned to a good hard body of buff colour.

These bricks show absolutely no indication of weathering; but, on the contrary, are hardening with age. The site of the brickyard at Moulinette was probably near the river bank just west of the English church, as some masses of fused and waste brick were found among the weeds at that point.

The brickyard that supplied Cardinal and vicinity was placed on a small patch of Champlain clay on lot 10 in the second concession, about 2 miles northwest of Cardinal. It was owned by James Sayer, and went out of operation about 10 years ago. It was stated that the workmen, who were getting 75 cents a day wages, demanded a dollar, so the owner decided he could not make money under these conditions, and closed down.

The prevailing rate of wages for labour in brickyards in 1908 was $1.25 to $2, the number of men employed being 5 to 12, according to output.

These brickyards supplied a very cheap but good structural material when it was most needed, hence they were extremely useful to the communities in which they were situated.

They were only operated during the summer months, but as the amount invested in the plant was small, they had little or no overhead expenses during the winter months when they were idle.

Future of the Clay Working Industry

Industries based on the Champlain clay are practically limited to three classes of product—building brick, hollow blocks, and field drain tile, but up to the present building brick seems to have been the only product made in the strip of country along the St. Lawrence. With the introduction of intensive farming, or improved farming methods, it is likely that there will be an increased use of tile for underdrainage. Underdrainage is specially needed in the flat lands underlain by Champlain clay, such as those in Soulanges, Vaudreuil, and Beauharnois counties, but at present it seems to be made use of very little, or not at all. A favourable site for a tile plant which could supply the greater part of these counties with brick and drain tile, has been indicated on a previous page.

One of the problems that troubles clayworkers to-day is that of fuel. Most of them use coal, but this fuel is becoming more expensive every year, and it is not always possible to provide an adequate supply. It is true that, while the large clay plants use coal, either direct fired, or turned to gas in producers, many of the smaller plants still continue to use wood for firing their kilns. There is an extensive area of forest land on the slopes of Rigaud mountain, in the northern part of Vaudreuil county, from which supplies of cordwood could be drawn in winter for use in a brickyard. As the greater portion of the upland of Rigaud mountain is unsuitable for agricultural purposes, it should prove a constant source of firewood if the woodlands are taken care of.

Hollow blocks made of burned clay have increased in use in recent years more than any other class of structural material. They have many advantages,

among them being cheapness of construction and better resistance to extremes of heat and cold than the ordinary solid walls.

Hard burned, hollow ware cannot be made from the Champlain clay, but it is possible to make the soft, porous kind known as terra cotta lumber, which is made from a mixture of clay, sand, and sawdust. The sawdust burns out and leaves cavities in the burned clay, so that nails can be driven into it. There is a large plant for the manufacture of this class of structural material at Lakeside, Quebec. Future plans for housing on a large scale at any point along the St. Lawrence should take into consideration the use of hollow blocks.

We have stated that the industry based on the Champlain clays and sands of the district is limited to a few classes of products, owing to the low fusibility of the clay, and the impossibility of making vitrified wares, such as sewer pipe, paving bricks, and floor tile. Many experiments have been made with a view to extending the usefulness of this clay by the addition of some cheap material. Keele has experimented with various mine wastes, such as the tailings from the graphite mines at Buckingham, and from the asbestos mines at Thetford; also with quicklime, marl, ground limestone, and dolomite, ground talc schist from Sherbrooke, and coal ashes. All of these materials were found to be valuable, chiefly in helping the working and drying qualities of the clay, particularly the use of quicklime in drying.

A detailed account of the effect of adding these materials is given in the report on the clay and shale deposits of the province of Quebec, Memoir 64, Geological Survey, Ottawa. The vitrification range was raised slightly, but some of the material had the effect of scumming the burned product.

The material to be added would have to be one that could be obtained conveniently and cheaply, such as the tailings from the silver mines at Cobalt, which are added to the brick clay at Haileybury[1] with good results.

Fireclay, or discarded fire brick, ground up fine enough, probably gives the best results for increasing the refractoriness of the Champlain clays; but any quantity less than about 35 per cent would not have much effect and there is no occurrence of fireclay that we are aware of along the St. Lawrence River valley. The nearest deposits to the district under consideration are in the province of Nova Scotia. This fireclay costs $4 per ton loaded on cars at the mine. The freight in 1920 to points in eastern Ontario was $8 to $10 a ton, so that fireclay is quite an expensive raw material to bring into this locality. If, in the future, ocean vessels can proceed to the ports on the upper St. Lawrence, it would be possible to bring over cargoes of Scotch or English fireclay at a cheaper rate.

In many places it is possible to accumulate a large supply of coal ashes convenient to a brick plant. This if ground would be a useful ingredient to add to the Champlain clay. It would have a certain fuel value on account of the particles of unburned or partly consumed coal, and it would help in the drying and increase slightly the range of vitrification. The ashes, however, would spoil the red colour of the burned ware; but this would not matter for hollow blocks or drain tile, where the ware is concealed behind a coating of plaster, or buried in the ground.

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[1] Mines Branch, Summary report, 1917, p. 103.

Silica Sand Industry

The Potsdam sandstones found in numerous outcrops in the vicinity of Beauharnois, Melocheville, and Cascades Point, province of Quebec, also in the outcrops on Isle Perrot, have some beds which are white, and which, when crushed, washed and dried, produce a silica sand that is suitable for several purposes. The most important industries which employ silica sand in one form or another are the glass industry, carborundum manufacture, steel foundries, and the pottery industry.

At the present time there is one company operating a silica sand plant in the district. (See Plate XXVII). This is the plant operated by the Consolidated Sand and Supply Company, Ltd., Melocheville, Quebec. The plant produces silica sand of two grades and sells it in Montreal to glass manufacturers and steel foundries.

The sand is produced from sandstone, quarried on the outskirts of the village. (See Plate XXVI). The stone is teamed to the mill, situated on the south bank of the east end of the Beauharnois canal, where it is crushed, ground, and screened.

The product is shipped in barges to the Montreal market. The following is a flow sheet of this mill:—

Flow Sheet—Melocheville Sand Plant

Rock (sandstone from quarry)—run of quarry.
Dodge jaw crusher to 2-inch size.
Grizzly $\frac{3}{8}$-inch space—oversize.

Disintegrator

Bucket elevator.
$\frac{1}{8}$-inch rotary trommel.
30 mesh inclined screen—oversize.
30 mesh material and finer.
Glass manufacturers—shipped to steel foundries.

The average throughput of this mill is 100 tons of crude rock per day, and the plant operates during the summer months only. The power to drive the mill is supplied by a steam boiler operating a 70 h.p. engine.

The following is the screen analysis of samples of the two products prepared at this mill, the first being of the coarse and the second of the fine sand:—

Retained on mesh	No. 1 Cumulative Per cent	No. 2 Cumulative Per cent
8	20·47	....
10	70·17	....
14	87·85	....
20	94·05	....
28	95·91	0·18
35	97·01	8·53
48	98·27	44·63
65	98·92	74·68
100	99·28	88·63
150	99·38	91·18
200	99·48	95·12

A chemical analysis of the material used for the glass industries, as represented by a sample taken from one of the barges loaded at the plant ready for shipment, gave the following results:—

	Per cent
SiO_2	98·25
Fe_2O_3	0·16
Al_2O_3	0·17
CaO	0·70
MgO	....
Loss on ignition	0·35

It is probable that this material could be improved by subjecting it to a thorough washing in standard type log washers, and afterwards drying before marketing.

There is a good market in Canada for silica sand of different grades, the glass industry alone consuming nearly 50,000 tons each year; and if the material from this district can be washed so that the silica content is above 99 per cent and the iron decreased, there should be a good opportunity for the extension of the silica sand industry in the district.

Glass Industry

The glass industry is closely allied to the silica sand industry, since silica sand is, in point of bulk, the most important ingredient of all glass.

It is doubtful if the manufacture of glass will be undertaken within the district covered by this report since there are so many factors entering into the question of the location of a glass plant, nearness to a sand supply being only of minor importance. The industry is of interest to the district, however; for it is one of the biggest consumers of the silica sand now being produced, and it is probable that it would use a considerably larger tonnage provided sand of sufficient purity can be produced for the higher grades of glass.

The requirements in a good glass sand include both physical and chemical properties, which may be enumerated as follows:

Texture.—The sand should be very uniform in grain, and 95 per cent should pass through 20 mesh (·833 mm. opening) and be retained on 100 mesh (·147 mm. opening). Glass manufacturers in most cases call for the grains to be angular, or semi-angular, in preference to rounded, as they state that the latter are more difficult to melt.

Chemical Composition.—Glass sand, as a general rule, should contain less than 1 per cent of iron oxide (Fe_2O_3), and in the case of the better grades of glass not more than 0·5 per cent. Lime, alumina, and magnesia may, in some cases, be permissible in small percentages, since for certain glasses these materials have to be added to the batch; but, as a general rule, it is best to depend on the sand only as a source of pure silica, and to add the other ingredients as required.

Thus, a good silica sand for use in the manufacture of glass is made up of uniform, angular grains, contains over 99 per cent silica, and is as free from iron as possible.

Carborundum Industry

A possible industry, incidental to the development of electrical power and the production of a high grade silica sand, is the manufacture of carborundum. For this industry cheap electrical power is needed, and a sand containing over 99·25 per cent SiO_2 and of uniform grade.

Sand for Steel Foundries

Silica sand for steel foundry use is now being produced in the district. The high temperature to which steel is subjected in the furnace, and which it retains on being poured into the mould, necessitates the employment of a highly refractory sand, hence, although some natural moulding sands are suitable for this work, the greater number of castings are made in moulds consisting largely of a high silica sand, to which some artificial bonding material has been added. The bonding material generally contains a highly plastic fireclay, flour, molasses, etc.

For this use, a sand running well over 95 per cent SiO_2 is necessary, and the tendency is towards increasing this minimum percentage. Iron oxide and other fluxing impurities are undesirable because they tend to increase the liability of failure of the mould, and to produce scabs on the casting. The sand should all pass through the 8 mesh (2·362 mm. opening) screen, and be retained on the 100 mesh (·147 mm. opening) screen, the greater bulk being between the 20 mesh (·883 mm. opening) and the 48 mesh (·295 mm. opening).

Concrete Structural Materials

There is a good opportunity for the establishment of several small plants for the manufacture of concrete blocks, drain tiles, etc., for local use. At the present time one plant is in operation 2 miles north of River Baudet, Que., where concrete blocks and drain tiles up to 3 feet inside diameter are being manufactured. At this plant the sand and gravel is obtained from the Baudet moraine.

Sand Lime Brick

These are building bricks made from a mixture of sand and lime, as the name implies. About 6 per cent of hydrated lime is added to the sand and thoroughly mixed. The mixture is pressed into brick shapes, and hardened under steam pressure in cylindrical steel chambers.

A medium to fine-grained, clean sand, composed mostly of quartz grains is used for this purpose. Sand from the deposits along the St. Lawrence, such as those in Williamsburg township, Dundas county, Ont., would be suitable.

Sand lime bricks of good quality have an established place in building practice, especially for interior basement walls, and for rear walls, where light coloured surfaces are required. Apart from this use, the sand lime brick fulfils no purpose for which the ordinary clay brick cannot be used.

Moulding Sand for Iron Foundries

Moulding sands are made up mostly of quartz grains with each individual grain coated with clay or silt, which acts as a bonding material when the sand is moistened.

They are generally found where deposits of sand and clay have been worked over by water, intermingled, and deposited on river terraces, flood plains, and raised beaches.

The greater part of the alluvial sand near the St. Lawrence river is not suitable for moulding, but at a few localities they appear to possess the requirements for use in iron and brass foundries.

One mile north of Bainsville, in Glengarry county, Ont., sand was noticed very similar in texture and composition to No. O Albany sand. This deposit is thin and of limited extent.

A larger deposit is situated on a farm $2\frac{1}{2}$ miles west of Cardinal, Ont., in the first concession, Edwardsburg township, Grenville county. Test pits on this sand have shown it to be four feet deep, in places. Samples collected by Mr. Wm. Leacy of Prescott, and tested in the Mines Branch laboratory, proved it to be similar to moulding sand obtained near Brockville,[1] and it corresponds very closely to No. 1 Albany sand, an American sand used in many of the foundries in Canada.

Sand very similar in appearance was seen on the roadside on lots 20 to 25 in the second concession, Edwardsburg township.

[1] Report on Occurrence and Testing of Foundry Moulding Sands. L. Heber Cole, Bulletin No. 21, Mines Branch, Department of Mines, No. 476, 1917.

APPENDIX

A

PLEISTOCENE AND RECENT FOSSILS OF THE ST. LAWRENCE VALLEY FROM PRESCOTT TO BEAUHARNOIS

BY

E. J. Whittaker

The different subdivisions of the Pleistocene of the St. Lawrence valley have been enumerated in the preceding report. The fossils here listed are from four distinct facies of the Pleistocene and Recent deposits:—

1. Alluvial deposits. Freshwater and marine fossils. (The latter from stream-eroded marine beds). Recent.
2. Clay and peat laid down in former ponds and swamps. Freshwater fossils only. Recent.
3. Marine sands and gravels (Champlain sands) Marine fossils. Pleistocene.
4. Marine clays. Marine fossils. Pleistocene.

FOSSIL LOCALITIES

Alluvial Deposits

River terraces, etc., of present streams:—

1. Low river terrace at S.E. corner Sheek island, St. Lawrence river, Cornwall tp.
2. Lot 6, con. VI, on small creek which crosses road, Charlottenburg tp., Glengarry co., Ont.
3. Sand terrace, lot 8, con. I, Osnabruck tp., Stormont co., creek near Wales Station, Ont.
4. At Black River, lot 26, con. III, Cornwall tp., Stormont co., Ont.

Peat and Swamp Deposits

5. At small creek at St. Louis de Gonzague, S.W. of St. Timothée, Beauharnois co., Que.

Marine Sands and Gravels

6. 3 miles W. of Prescott, on bank of St. Lawrence just south of Blue Church.
7. At intersection of Grand Trunk Railway and Canadian Pacific Railway tracks just east of Prescott, Ont.
8. Gravel pit, lot 8, con. II, Williamsburg tp., Dundas co., Ont., midway between Morrisburg and Aultsville, on north side of road.
9. Hamilton gravel pit, lot 31, con. VI, Osnabruck tp., Stormont co.
10. Hollister pit, lot 27, con. IV, Osnabruck tp., near Gallingertown, Ont.

11. Windfall pit, lot 36, con. III, Cornwall tp., Stormont co., near Mille Roches, Ont.
12. Frank Lefevre gravel pit, lot 21, con. 5, Charlottenburg tp., Glengarry co., near Williamstown, Ont.
13. Beaupre pit, lot 6, con. VIII, Charlottenburg tp., Glengarry co., 6 miles west of North Lancaster.

MARINE CLAY

14. Lot 3, con. I, Williamsburg tp., Dundas co., Ont., near Aultsville on bank of St. Lawrence river.
15. In bank of small creek which crosses road just west of and leading north from Farran Point, just east of bridge which crosses road and one-fourth of a mile from St. Lawrence river.
16. 1 mile west of Dickinson Landing, Ont., on bank of St. Lawrence river.
17. Opposite Moulinette, on Sheek island, St. Lawrence river.
18. 4 miles west of Melocheville, Beauharnois co., Quebec, on bank of St. Lawrence river.

In the Champlain clays[1] the following species were noted in the field collections[2]:—

PORIFERA

Tethea (Craniella) logani, Dawson. rare, 16.

MOLLUSCA

Portlandia arctica, Grey, abundant. 14, 15, 18.
Saxicava rugosa, Lamarck. rare, 14, 15, 16.
Nucula tenuis, Montagu. rare, 16.
Leda minuta, Fabricius. rare, 15.
Mytilus edulis, Linn. rare, 15.
Macoma calcarea, Gmelin. rare, 18.
Macoma balthica, L. abundant, 14-18.
Natica clausa, Brod. and Sow. 15.

CRUSTACEA

Balanus crenatus, Brug. rare, 16.

In the marine fauna of the Champlain or Saxicava sands the following species were noted:—

MOLLUSCA

Saxicava rugosa, L. common, 6, 8, 10-12.
Macoma balthica, L. very common, 6-13.
Mytilus edulis, L. rare, 10.
Mya arenaria, L. 12, 13.

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[1] See "The Pleistocene and Recent Deposits of the Island of Montreal" by J. Stansfield. Memoir 73. Geological Survey, Dept. of Mines, Canada, pp. 65-68, for complete lists of Pleistocene and Recent fossils of the Island of Montreal.

[2] In the succeeding lists the number following each species indicates that it was found at the locality designated by that number in the above list of fossil localities.

CRUSTACEA

Balanus hameri, Ascanius, 10.
Balanus crenatus, Brug. 10, 11.

The swamp and pond deposits furnished the following species from the base of a peat bed a short distance only above the marine clay at locality 5.

MOLLUSCA

Calyculina securis, Prime.
Pisidium abditum, Haldeman.
Pisidium compressum, Say.
Pisidium sp.
Amnicola porata, Say.
Planorbis parvus, Say.
Planorbis exacuous, Say.
Planorbis antrosus, Conrad.
Valvata tricarinata, Say.
Valvata tricarinata, var.
Valvata bicarinatus, var. normalis, Walker.
Valvata sincera, Say.
Lymnaea (Galba) palustris, Muller.
Lymnaea sp. c.f. stagnalis appressa, immature specimens.
Ancylus rivularis, Say.

The following species were obtained in the alluvial deposits:—

MOLLUSCA

Anodonta grandis footiana, Lea, 2. *Anodontoides ferussacianus,* Lea, 2. *Sphaerium solidulum,* Say, 1. *Sphaerium rhomboideun,* Say, 4. *Sphaerium simile,* Say, 2, 3. *Pisidium sp.,* 3.	Fresh water forms.
Lymnaea (Galba) palustris, Muller, 2, 3. *Planorbis antrosus,* Conrad, 3. *Planorbis parvus,* Say, 2, 3. *Physa ancillaria,* Say, 4. *Physa heterostropha,* Say, 2, 4. *Amnicola porata,* Say, 3, 4. *Pomatiopsis lustrica,* Pilsbry, 3. *Valvata tricarinata,* Say, 3.	Fresh water forms.
Pleurocera sublare, Say, 1. *Pleurocera elevatum,* Say, 1. *Campelona subsolidum,* Anthony, 1.	Fresh water forms.
Saxicava rugosa, L., 3, 4. *Macoma balthica,* L., 3, 4. *Macoma calcarea,* Gmelin, 4. *Portlandia arctica,* Gray, 3, 4.	Marine forms.

CHAMPLAIN CLAYS

Interest centres largely in the fauna of the Champlain sands and clays, owing to the association of these sands and clays with the other Pleistocene deposits. Fossils are rare in the marine clay, as a rule, except in certain beds which are very prolific in specimens. Large areas of the marine clay may be searched without result, and, while the total number of forms is large, only a few species are found at any one locality. Searching for fossils in the marine clays is usually difficult, as sections occur only in the banks of the St. Lawrence and its tributaries, and the surface drainage makes these clay banks very slippery and muddy. One of the most prolific fossil localities is the bank of a small brook which crosses the road just west of and leading north from Farran Point. At this exposure there is about six feet of marine clay overlain by a bed of sand. The fossils are practically confined to a thin layer about two feet from the bottom of the section. One mile west of Dickinson Landing there is a section of 10 feet of clay, which contains besides the common members of the fauna, considerable numbers of the sponge *Tethea (Craniella) logani.* This cannot usually be seen in the field except by washing out with a sieve. The fine siliceous spicules are readily recognized with a lens. Isolated sponge spicules are found commonly throughout the marine clay. Just west of Aultsville, there is a section of 12 feet of sand overlying 5′+ of marine clay where the common species occur, but poorly preserved. Farther east fossiliferous marine clays occur 4 miles west of Melocheville, Quebec, on the river bank. At this locality *Portlandia arctica* is large and abundant.

Portlandia arctica is the most persistent and characteristic fossil of the whole marine clay fauna. Formerly called *Leda glacialis,* its name was given by Sir J. W. Dawson to these deposits, which he called Leda clays. Mature specimens measure 15 mm. in length and 8 mm. in height, but many individuals are less than half these measurements where conditions were unfavourable. As a rule, the less silt or sand in the clay the larger the size attained by these pelecypods.

Macoma balthica, while present in the clay, is small compared to the forms occurring in the sand and gravel deposits.

The following measurements are a fair average:—

Macoma balthica {Marine clay. Height 12 mm. Length 16 mm.
{Sand. Height 21 mm. Length 26 mm.

A large percentage of the specimens of *M. balthica* in the clays, show by their thin shells and indistinct dentition and muscle scars that they are immature forms, which did not long survive the unfavourable environment. Owing to the great variability in *Saxicava rugosa* it is impossible to give for that species such definite comparisons as the above, but in general the specimens in the clay are smaller than those in sand and gravel.

The barnacle *Balanus crenatus,* found rarely in the Champlain clays of this area, has been washed down from shallower waters in most cases.

Sands and Gravels of Champlain Age

These formations, which occur irregularly scattered over a considerable part of the area, are well shown on the maps accompanying the report. Certain species of the marine fauna are nearly always found wherever these gravels

are exposed, but a few localities are of especial interest. Among these are the Beaupre pit, the Hollister pit, and the Windfall pit. The position of these are indicated in the previous report. In the Beaupre pit the section as described by Mr. Cole is as follows:—

Beach shingle on top.
Clay and sand, with *Mya arenaria* only.
Gravel, with *Macoma balthica* common.
Gravel, with *Saxicava rugosa* common.
Boulder clay.

Mya arenaria, the common class, was found west of this locality at one place only, on lot 21, con. V, Charlottenburg tp., Glengarry county, at the Frank Lefevre pit. The specimens from the Beaupre pit are large and well-developed, in contrast with the stunted, ill-developed forms from the Lefevre pit. *Mya* is a characteristically intertidal species, while *Macoma* and *Saxicava* are shallow water forms. At the Hollister pit a section of about 17 feet is exposed, consisting of huge boulders 1 foot and over in diameter at the top, with finer material below and filling the interstices between the larger boulders. In this finer material *Saxicava* and *Macoma* are found in perfect preservation, with the valves united, while the fragile barnacles *Balanus crenatus* remain attached in their original position to the larger boulders. Considering the perfect preservation of the fossils it seems unlikely that the large boulders were subjected to very heavy wave action, otherwise in rolling about the fragile shells would have been crushed. It is possible that when the morainic ridge was being reworked by the waves, these large boulders were shifted very little from their original positions. *Saxicava* and *Macoma* while present throughout the section are especially abundant about six feet from the top. At the Windfall pit, which is a beach deposit of roughly stratified material cut out of the old morainal ridge, there is the same fauna as that at the Hollister pit, except that the shells of *Saxicava* are much smaller and more rare in the upper portion of the section. The smaller size is due to a less favourable environment—possibly warmer or fresher water.

Three miles west of Prescott, on the river road just south of the Blue Church, a bluff facing the river contains in abundance *Macoma balthica* and, very rarely, *Saxicava rugosa*. At this locality, about twelve feet of sand lies against a sloping bank of roughly stratified blue clay containing a few boulders. The clay is apparently a boulder clay though more brittle than usual. The fossils are largely confined to certain bands in the sand, in which, however, they are very abundant. At the very top of the section boulders occur rarely. This was the most westerly exposure seen by the writer, but many years ago Dr. Robert Bell found traces of marine fossils in clay in an excavation for a tunnel under the town of Brockville, eight miles farther west.

There is a most interesting fossil occurrence in a small ditch at the intersection of the Canadian Pacific Railway and Grand Trunk Railway tracks just east of Prescott. At this section there are two feet of fine silty sand covered by about two feet of coarser rust-stained sand and a thin layer of top soil. In the lower fine sand there are great numbers of large *Macoma balthica*, the shells of which have the epidermis largely preserved. This is quite unusual. The specimens have not been subject to much wave action, as the two valves are commonly united and the epidermis has not been abraded.

Macoma balthica is found farther west than any of its contemporaries in these beds, and more readily adapted itself to unfavourable conditions, in this case fresh water from the west. In contrast, the westerly limit of *Mya arenaria* is fifty-five miles east, farther down the river. The barnacles also could not stand fresh water so well and their westerly limit is over thirty miles east of that of *Macoma balthica*. *Saxicava* occupies nearly the same territory, though not quite so far west as the latter, but is rarer at the western limit. When the total number of species given above is compared with the large list from Montreal[1], it is readily seen that the fauna becomes constantly more sparse toward the west. This fact is verified by the examination of Pleistocene deposits farther east, from Three Rivers and Quebec, with their abundant and diversified fossil remains.

No vertebrate fossil remains were collected in this area.

As a whole the fauna is simple compared with that found in beds of similar age in the Ottawa valley and does not extend as far west as the latter. It is probable that the great influx of fresh water from the west into the Gulf was effective in restricting the number of species which could live under these conditions. Farther east, the water was more salty and more species could survive. A similar condition can be seen at the present time farther down the St. Lawrence. At Murray Bay sea shells are rare; at Tadousac they are more plentiful and of more species; and farther down are still more common. On the other hand the amount of fresh water coming down the Ottawa valley was too small to make the sea water very brackish and a more diversified fauna was established.

PEAT DEPOSITS

A fresh water fauna associated with clay and peat was found in a small creek near St. Louis de Gonzague, southwest of St. Timothée. These rest directly on marine clay and the fossils were picked from a bed only three inches above the clay.

ALLUVIAL DEPOSITS

These deposits have been formed by streams which have cut through all the different members of Pleistocene and Recent age. In consequence they include many of the marine fossils which have been washed out of the older beds and also a modern freshwater fauna of molluscs which lived in the streams and whose dead shells are thus intermingled with the earlier forms. As neither these beds nor the peat deposits have any great geological significance they are not further discussed in this paper.

[1] The discrepancy between the list in Memoir 73 by Mr. Stansfield and the list quoted above is more apparent than real, as the former contains all the species discovered during many years, while the latter records only those discovered by the party in 1919 and 1920.

B

ORDOVICIAN FOSSILS FROM ST. LAWRENCE CANAL SYSTEM LOCALITIES, ONTARIO AND QUEBEC

COLLECTED BY

L. H. Cole and J. Keele

IDENTIFIED BY

Alice E. Wilson

G.S.C. Loc. 6336, quarry at lot 27, con. V, Osnabruck tp., Stormont co., Ont. Trenton formation.

Prasopora sp.
Dalmanella rogata (Sardeson).
Rafinisquina alternata (Emmons).
Zygospira recurvirostris (Hall).
Rhynchotrema increbescens (Hall).
cf. *Modiolon patulus* (Ulrich).
Liospira sp.
Calymene senaria (Conrad).
Ceraurus sp.
Ostracoda.

G.S.C. Loc. No. 6344, lot 26, con. III, Cornwall tp., Stormont co., Ont. Lower Trenton beds.

Dalmanella rogata (Sardeson).
Plectambonites sericeus (Sowerby).
Rafinisquina alternata (Emmons).
Strophomena filitexta (Hall).
Rhynchotrema increbescens (Hall).
Zygospira recurvirostris (Hall).
Dinorthis pectinella (Emmons).
Hormotoma bellicincta (Hall).
Hormotoma gracilis (Hall).

G.S.C. Loc. 6327, lots 4, 5, 6, con. IV, Cornwall tp., Stormont co., Ont. Trenton formation.

Rafinisquina camerata (Conrad).
Pleurotomaria agave (Billings).

G.S.C. Loc. 6322, lot 20, con. IV, Charlottenburg tp., Glengarry co., Ont. Trenton formation.

Bryozoa.
Plectambonites sericeus (Sowerby)
Parastrophia hemiplicata (Hall).
Platystrophia trentonensis (McEwan).
Liospira sp.
Hormotoma sp.
Pterygometopus sp.

G.S.C. Loc. No. 6323, lot 45, con. VII, Charlottenburg tp., Glengarry co., Ont. Trenton formation.

Dalmanella rogata (Sardeson)
Rafinisquina alternata (Emmons).
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).
Isotelus sp.—fragments.
Bumastus sp.—cephalon.

G.S.C. Loc. No. 6324, lot 46, con. VII, Charlottenburg tp., Glengarry co., Ont. Trenton formation.

Bryozoa.
Rafinisquina alternata (Emmons).
Dalmanella rogata (Sardeson).
Zygospira recurvirostris (Hall).
Pterygometopus cf. callicephalus (Hall).

G.S.C. Loc. No. 6357, three-fourths of a mile east of Bouckhill, lot 21, con. V, Williamsburg tp., Dundas co., Ont. Black River.

Crinoid stems.
Tetradium cellulosum (Hall).
Bryozoa.
Dalmanella rogata (Sardeson).
Pianodema subaequata (Conrad).
Crytodonta sp.
Lophospira perangulata (Hall).
Bathyurus extans (Hall).

G.S.C. Loc. No. 6358, one-half mile north of Bouckhill, lot 24, con. V, Williamsburg tp., Dundas co., Ont. Black River or Trenton.

Crinoid stems.
Rhinidictya sp.
Dalmanella rogata (Sardeson).
Strophomena filitexta (Hall).
Zygospira recurvirostris (Hall).
Bumastus sp.
Ostracod.

G.S.C. Loc. No. 6359. In the bed of a creek, lot 11, con. VII, Williamsburg tp., Dundas co., Ont. Trenton.

Prasopora sp.
Zygospira recurvirostris (Hall).
Maclurites sp.
Ceraurus sp.
Bumastus trentonensis.
Ostracoda.

1. Southeast of Melocheville, Que. Beekmantown.
Ophileta complanata (Vanuxeum).

2. Maple Grove, Que., just east of Beauharnois. Beekmantown.
Tryblidium sp.
Ophileta complanata (Vanuxeum).

3. Lots 34 and 35, con. VI, Williamsburg tp., Dundas co., Ont. Black River: Lowville.
   Tetradium cellulosum (Hall).
   Tetradium halysitoides (Raymond).
   Cyrtodonta sp.
   Liospira sp.
   Leperditia sp.

4. Bed of creek one-half mile east Black River station, New York Central Ry., Ont. Trenton limestone.
   Bryozoa—undetermined.
   Phaenopora sp.
   Prasopora sp.
   Dalmanella rogata (Sardeson).
   Rafinisquina alternata (Emmons).
   Dinorthis pectinella (Emmons).
   Strophomena sp.
   Zygospira recurvirostris (Hall).
   Plectambonites sericeus (Sowerby).

5. About 2 miles northeast of Valleyfield, Que., on DeSalaberry island. Beekmantown.
   cf. *Orthis apicalis* (Billings).
   Hormotoma anna (Billings).
   Hormotoma cf. cassina (Whitfield).
   Isoteloides whitfieldi (Raymond).
   Dolichometopus ? rarus (Billings)
   Goniurus sp.

PLATE I

Stream erosion on bank of St. Lawrence river, at Farran Point, Ontario.

PLATE II

Meandering stream entrenched on clay plain at St. Lazare, Que.

PLATE III

Typical topography in Cornwall morainal belt near headwaters of Baudet river.

PLATE IV

Farming land in Cornwall morainal belt. Church of St. Raphael, Glengarry county. Ontario, in distance.

PLATE V

Clay plain, with wooded patches, Soulanges co., Que.

PLATE VI

Slides on clay bank, between Cedars and Cascades rapids, Que.

PLATE VII

Boulder clay, east bank of creek near Farran Point. This is a typical example of the boulder clay or till of this region.

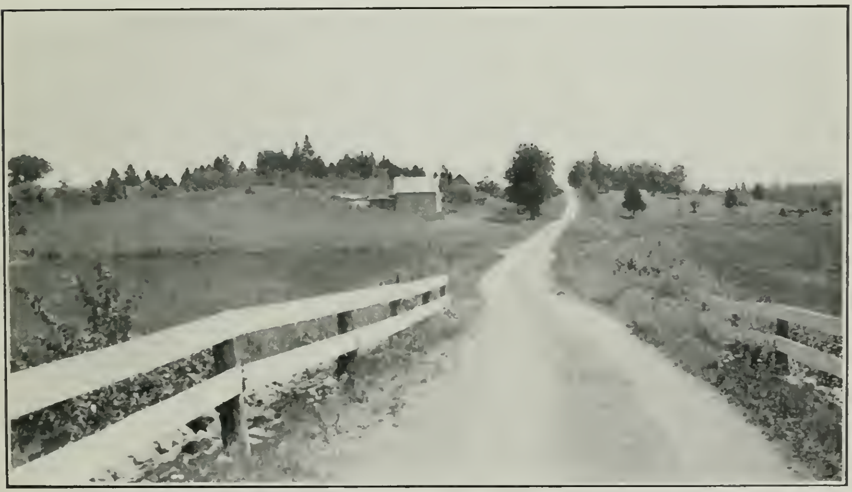
PLATE VIII

Typical exposure of freshly excavated upper marine clay in St. Lawrence valley.

PLATE IX

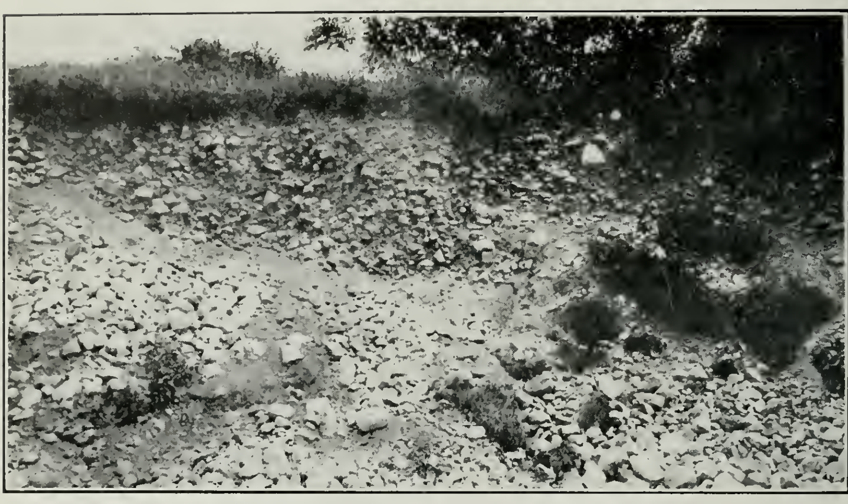
Clay terrace, west of Vaudreuil, Que.

PLATE X



Low ridge, with deposit of marine beach gravel along the northwestern flank. Cornwall tp., Stormont co., 1 mile west of Black River station, New York and Ottawa railway.

PLATE XI



Gravel pit in beach ridge shown in Plate X.

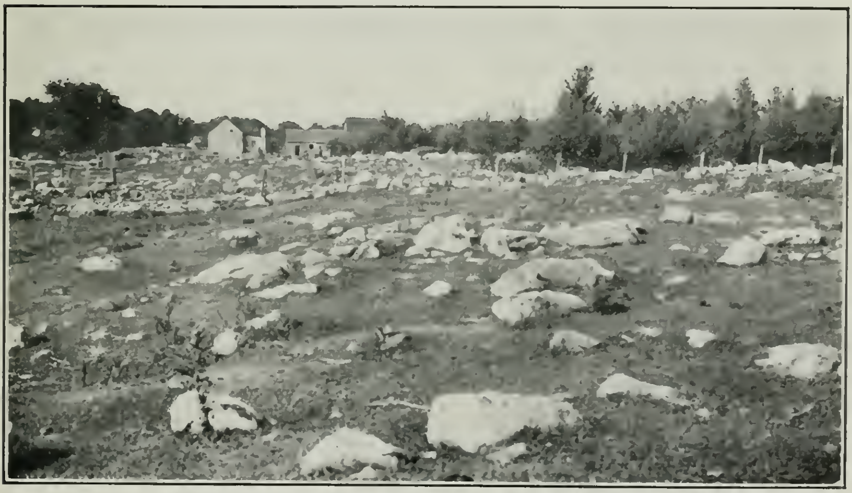
PLATE XII

Sand ridge, partly wooded. Cultivated portion in foreground is now drifting and useless, since removal of forest. Lot 4, con. IX, Augusta township, Grenville co., Ont.

PLATE XIII

Sand drifting from ridges as the result of continued cultivation.
Lot 27, con. III, Edwardsburg township, Grenville co., Ont.

PLATE XIV



Excessively stony ridge, Beauharnois county, Que.

PLATE XV

Stony ridge, partly wooded, three miles east of Martintown, Glengarry county, Ont.

PLATE XVI

Boulders and blocks on stony ridge 1 mile south of St. Raphael, Ont. Large limestone block in centre has over 100 tons showing above surface.

PLATE XVII

Huge granite erratic, 2 miles north of Mille Roches, Ont. Over 135 tons above surface.

PLATE XVIII

Potsdam sandstone quarry in bed of St. Louis river, Beauharnois, Que.

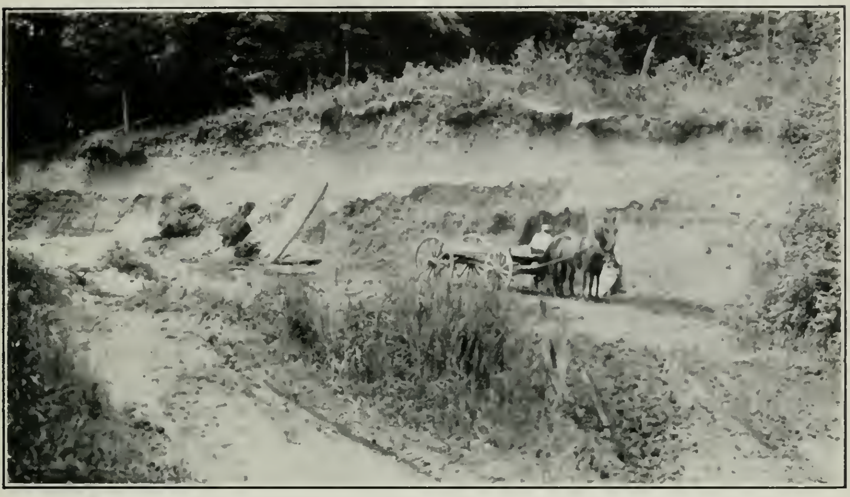
Plate XIX

Model of Windfall gravel pit. Typical beach deposit.

Plate XX

Gravel pit, showing stratification and bed-rock floor.

PLATE XXI



Gravel pit east of Ventnor, Ont. Typical deposit of fluvio-glacial origin.

PLATE XXII

Hollister gravel pit, Osnabruck tp., Stormont co., Ont.

PLATE XXIII

Shallow gravel pit, with large percentage of cobbles. Lot 16, con. V, Osnabruck tp., Stormont co., Ont.

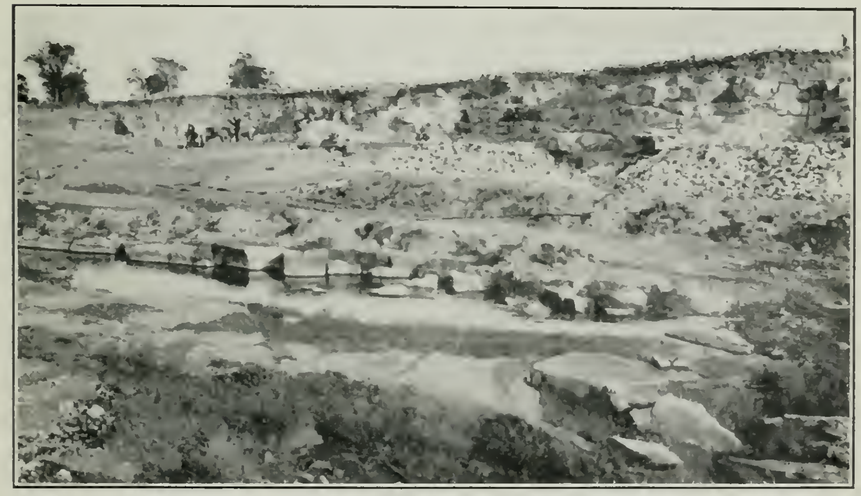
PLATE XXIV

Mitchell gravel pit, Charlottenburg tp., Glengarry co., Ont.

PLATE XXV

Beaupré gravel pit, Charlottenburg tp., Glengarry co., Ont.

PLATE XXVI



General view of Potsdam sandstone quarries at Melocheville, Que.

PLATE XXVII

Plant for crushing sandstone at Melocheville, Que.

PLATE XXVIII

Abandoned quarry in Beekmantown dolomite, one and a half mile west of Cardinal, Ont.

Quarry in Beekmantown dolomite on property of Mr. Arsene Meloche, near St. Louis de Gonzague, Beauharnois county, Que. Road material sample No. 254.

Beds of Beekmantown dolomite in Laberge quarry near Chateauguay, Que. Used for road material on Woodlands-Chateauguay road. Road material sample No. 257

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Canada
Department of Mines

MINES BRANCH
JOHN McLEISH, Director

EXPLANATORY NOTES

SWAMPS

The areas mapped as swamps are wet during the greater part of the year, and some of them are never dry even in the dryest summer. Nearly all the swamps are wooded and some of them support a dense growth of trees. Swampy areas are constantly being drained wherever possible and if the underlying soil is suitable, the drained areas are cleared and turned over to cultivation. Not all the land below the swamps, however, is suitable for cultivation.

SANDS

The areas mapped as sands are mostly extensive plains of Champlain or marine sands, but included within these areas are small patches of silt or clay with indefinite boundaries between them and the sand. Terrace sands along the St Lawrence river in places and occasional mounds or ridges of wind blown sand are also included under the general colour for sand.

Ridges and mounds of sands which have considerable topographical relief and which are believed to be earlier and of a different origin to the above are shown in a different colour.

Most of the sands are of fine grain too fine for use even for mortar or sand lime brick. They are of little economic value. Small quantities of sand suitable for use in mortar or in concrete aggregates can be obtained from the beach gravel deposits. The best sands of the region are those from the fluvio glacial deposits.

GRAVELS

Most of the gravel deposits along the St Lawrence river are in the form of raised beaches of marine origin. They are never very extensive but are widely distributed in some portions of the region and are largely utilized for road material, or for concrete construction. Only a few of the deposits are of fluvio-glacial origin, but these are generally the most desirable gravels for concrete construction being cleaner.

Minor amounts of sand are obtained from both deposits.

CHAMPLAIN CLAY

This clay is widespread in the region and sometimes forms continuous flat areas of large extent. The clay also forms the subsoil of most of the land over which the Champlain sand is spread. The best farming lands in the region are underlain by Champlain clay.

This clay is very plastic, often sticky after rains and is absolutely stoneless. When mixed with a certain proportion of sand it may be used for the manufacture of building brick or field drain tile.

BOULDER RIDGES

These ridges are more stony than the land in the surrounding country. They are frequently so thickly strewn with stones, boulders or blocks of limestone as to render them absolutely unfit for cultivation or even pasturage, but they can be used as a source of valuable hardwood. The boulder accumulations on these ridges can be used for road building or for farm buildings.

BOULDER CLAY OR TILL

This is the most widespread surface material in the region. It is a glacial deposit consisting of an unsorted mixture of stones, gravel, sand, silt and clay in varying proportions. Some of the best soils result from the weathering of the surface of the more clayey types of till, but where sand and stones predominate it may be almost barren especially in dry seasons.

The till or boulder clay is often known as glacial drift, and many of the stones contained in it have been moved for long distances from their place of origin.

The lower parts of the till are frequently dense and hard so that it is difficult to excavate. The name "hard pan" is often used for this formation.

BEDROCK OUTCROPS

Bedrock outcrops are not very numerous in the central area covered by these sheets, the drift covering in this district being heavy. In the Morrisburg sheet and also the Valleyfield sheet the rock floor in places comes nearer to the surface and considerable areas are to be found with actual outcrops or with only a thin covering of drift over the rock. The rocks, with only one exception, are of Paleozoic age and consist of sandstones, dolomites and limestones. One area of very small extent about 2 miles northeast of Prescott was noted where Archean quartzite outcropped through surrounding Paleozoic rocks. The Paleozoic rocks are, in many localities, suitable for building purposes and the sandstone in the Beauharnois district is of sufficient purity to be ground for glass manufacture and for use in steel foundries. Where convenient and available the limestone or dolomite is being crushed for road surfacing and in some localities has been used for the manufacture of lime.

Based on map published by the Department of Militia and Defence

VALLEYFIELD SHEET
St LAWRENCE RIVER SECTION
QUEBEC

Scale, 63360 1 Mile to 1 Inch

Elevation in feet (150) above sea level

GEOLOGY
J Keele
L Heber Cole } 1919-1920
J Stansfield 1918

To accompany report on "Structural Materials along the St Lawrence River valley" Mines Branch Ottawa Report No 549

Note For Sections A-B, C-D, E-F and G-H see Fig 8 in report

Canada
Department of Mines

MINES BRANCH
JOHN McLEISH Director

LEGEND

RECENT
- Swamps
- Peat bogs
- Sands: Champlain (marine) and dune sands

PLEISTOCENE
- Gravels: marine beach and fluvio glacial gravels
- Champlain clay (marine)
- Boulder ridges (moraines)
- Boulder clay or till
- Thin drift cover over bedrock

PALEOZOIC
- Bedrock outcrops

CORNWALL SHEET
ST LAWRENCE RIVER SECTION
ONTARIO AND QUEBEC

Scale 1/63360 1 Mile to 1 Inch

GEOLOGY
J Keele
L Heber Cole } 1919 1920

To accompany report on "Structural Materials along the St Lawrence River valley"
Mines Branch, Ottawa, Report No 588

EXPLANATORY NOTES

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Ridges and mounds of sands which have considerable topographical relief and which are believed to be earlier and of a different origin to the above, are shown in a different colour.

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GRAVELS

Most of the gravel deposits along the St Lawrence river are in the form of raised beaches of marine origin. They are none very extensive but are widely distributed in some portions of the region, and are freely utilized for road material or for concrete construction. Only a few of the deposits are of fluvio glacial origin, but these are generally the most desirable gravels for concrete construction being cleaner.

Minor amounts of sand are obtained from both deposits.

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This clay is widespread in the region and sometimes forms continuous flat areas of large extent. This clay also forms the subsoil of most of the land over which the Champlain sand is spread. The best farming lands in the region are underlain by Champlain clay.

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These ridges are more stony than the land in the surrounding country. They are frequently so thickly strewn with stones, boulders or blocks of limestone as to render them absolutely unfit for cultivation or even pasturage, but they can be used as a source of valuable hardwood. The boulder accumulations on these ridges can be used for road building or for farm buildings.

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This is the most widespread surface material in the region. It is a glacial deposit consisting of an unsorted mixture of stones, gravel, sand, silt and clay in varying proportions. Some of the best soils result from the weathering of the surface of the more clayey types of till, but where sand and stones predominate it may be almost barren especially in dry seasons.

The till or boulder clay is often known as glacial drift, and many of the stones contained in it have been moved for long distances from their place of origin.

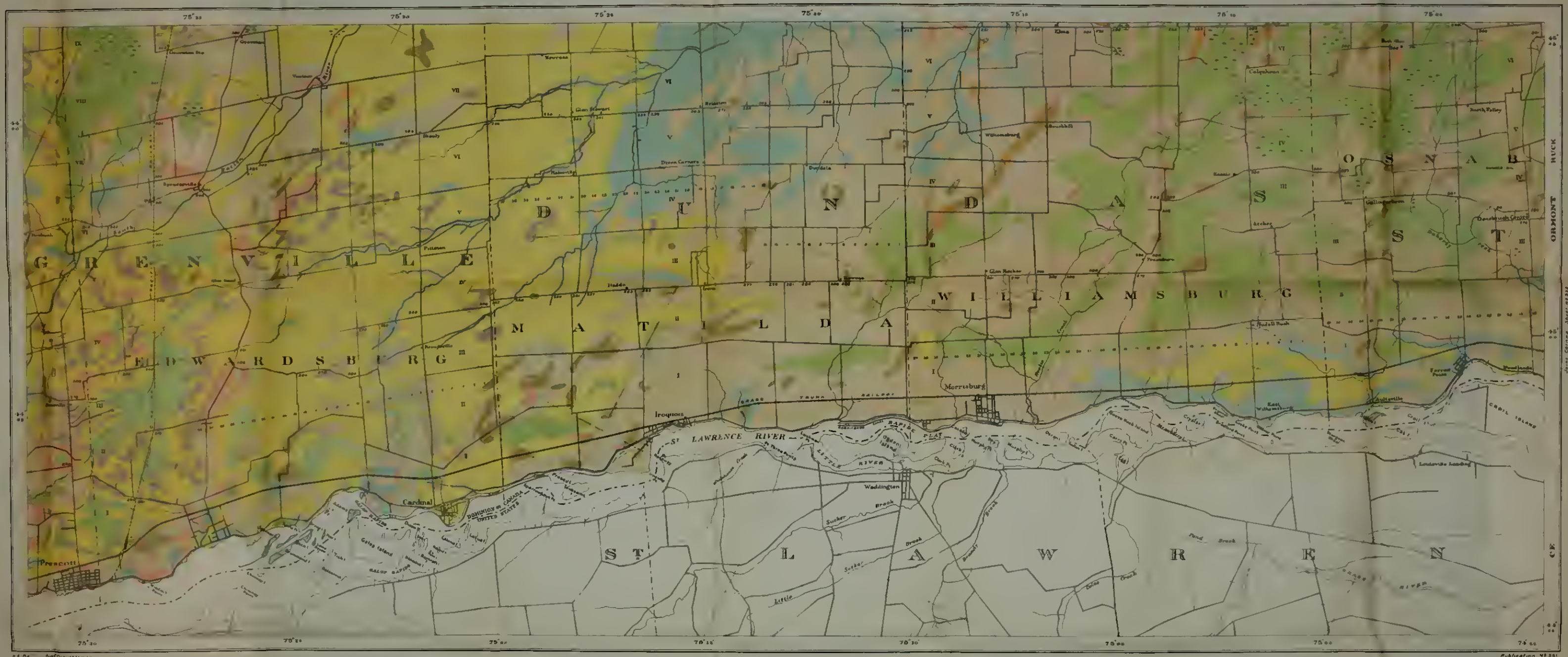
The lower parts of the till are frequently dense and hard so that it is difficult to excavate. The name "hard pan" is often used for this formation.

BEDROCK OUTCROPS

Bedrock outcrops are not very numerous in the central area covered by these sheets, the drift covering in this district being heavy. In the Morrisburg sheet and also in a Valleyfield sheet the rock floor in places comes nearer to the surface and considerable areas are to be found with actual outcrops or with only a thin covering of drift over the rock. The rocks with only one exception are of Paleozoic age, and consist of sandstones, dolomites and limestones. One area of very small extent, about 2 miles northeast of Prescott was noted where Archean quartzite outcropped through surrounding Paleozoic rocks. The Paleozoic rocks are in many localities suitable for building purposes and the sandstone in the Beauharnois district is of sufficient purity to be ground for glass manufacture and for use in steel foundries where convenient and available the limestone or dolomite is being crushed for road surfacing, and in some localities has been used for the manufacture of lime.

Canada
Department of Mines

MINES BRANCH
JOHN McLEISH, Director
[illegible]



LEGEND

RECENT
- Swamps
- Peat areas

PLEISTOCENE
- Sands (Champlain sands and dune sands)
- Gravels (Marine beach and fluvio-glacial gravels)
- Champlain clay (Marine)
- Sand ridges (Marginal)
- Boulder ridges (Morainic)
- Boulder clay or till
- Thin drift cover over bedrock

PALEOZOIC
- Bedrock outcrops

EXPLANATORY NOTES

SWAMPS

The areas mapped as swamps, are wet during the greater part of the year, and some of them are never dry even in the dryest summer. Nearly all the swamps are wooded, and some of them support a dense growth of trees. Swampy areas are constantly being drained, wherever possible and if the underlying soil is suitable, the drained areas are cleared and turned over to cultivation. Not all the land below the swamps however is suitable for cultivation.

SANDS

The areas mapped as sands are mostly extensive plains of Champlain or marine sands but included within these areas are small patches of silt or clay with indefinite boundaries between them and the sand. Terrace sands along the St Lawrence river in places and occasional mounds or ridges of wind blown sand are also included under the general colour for sand.

Ridges and mounds of sands which have considerable topographical relief and which are believed to be earlier and of a different origin to the above are shown as different colour.

Most of the sands are of fine grain, too fine for use even for mortar or sand lime brick. They are of little economic value. Small quantities of sand suitable for use in mortar or in concrete aggregates can be obtained from the beach gravel deposits. The best sands of the region are those from the fluvio glacial deposits.

GRAVELS

Most of the gravel deposits along the St Lawrence river are in the form of raised beaches of marine origin. They are never very extensive but are widely distributed in some portions of the region and are freely utilized for road material or for concrete construction. Only a few of the deposits are of fluvio glacial origin but these are generally the most desirable gravels for concrete construction being cleaner.

Minor amounts of sand are obtained from both deposits.

CHAMPLAIN CLAY

This clay is widespread in the region and sometimes forms continuous flat areas of large extent. The clay also forms the subsoil of most of the land over which the Champlain sand is spread. The best farming lands in the region are underlain by Champlain clay.

This clay is very plastic, often sticky after rains and is absolutely stoneless. When mixed with the certain proportion of sand it may be used for the manufacture of building brick or field drain tile.

BOULDER RIDGES

These ridges are more stony than the land in the surrounding country. They are frequently so thickly strewn with stones boulders or blocks of limestone as to render them absolutely unfit for cultivation or even pasturage but they can be used as a source of valuable hardwood. The boulder accumulations on these ridges can be used for road building or for farm buildings.

BOULDER CLAY OR TILL

This is the most widespread surface material in the region. It is a glacial deposit consisting of an unsorted mixture of stones gravel sand silt and clay in varying proportions. Some of the best soils result from the weathering of the surface of the more clayey types of till but where sand and stones predominate it may be almost barren especially in dry seasons.

The till or boulder clay is often known as glacial drift and many of the stones contained in it have been moved for long distances from their place of origin.

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BEDROCK OUTCROPS

Bedrock outcrops are not very numerous in the central area covered by these sheets the drift covering in this district being heavy. In the Morrisburg sheet and also the Valleyfield sheet the rock floor in places comes nearer to the surface and considerable areas are to be found with actual outcrops or with only a thin covering of drift over the rock. The rocks with only one exception are of Paleozoic age and consist of sandstones dolomites and limestones. One area of very small extent about 2 miles northeast of Prescott was noted where Archean quartzite outcropped through surrounding Paleozoic rocks. The Paleozoic rocks are in many localities suitable for building purposes and the sandstone in the Beauharnois district is of sufficient purity to be ground for glass manufacture and for use in steel foundries where convenient and available the limestone or dolomite is being crushed for road surfacing and in some localities has been used for the manufacture of lime.

Based on map published by the Department of Militia and Defence

MORRISBURG SHEET
ST LAWRENCE RIVER SECTION
ONTARIO

Scale, $\frac{1}{63360}$ 1 Mile to 1 Inch

Elevation in feet (275) above sea level

GEOLOGY
J Keele
L Heber Cole } 1919-1920

To accompany report on Structural Materials along the St Lawrence River valley
Mines Branch Ottawa Report Nº 549

Note For section J K see Fig 8 in report

Publication Nº 551